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FINAL ENGINEERING REPORT

INVESTIGATION OF RELIABILITY-GROWTH INCENTIVES AND ANALYSIS OF IOT&E TEST DATA FOR AFSATCOM

31 December 1975

Prepared for
AIR FORCE LOGISTICS COMMAND
Wright Patterson Air Force Base
Dayton, Ohio
under Contract F09603-75-A-3001-0003

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FOREWORD

This final report summarizes work performed by ARINC Research Corporation under Delivery Order 0003 of Contract F09603-75-A-3001 during the period of 6 February 1975 through 31 December 1975.

The work reported on was performed for AFLC/AQ in order to derive guidelines, for future procurements, in the areas of life-cycle-costs (LCC) controls and utilization of IOT&E test data for reliability assessment. The study equipment was AFSATCOM -- an assortment of many different LRUs combined in various ways to produce airborne and ground-based communications terminals. The report is written as a chronological documentation, with lessons learned and conclusions and recommendations appearing in the report as they emerged during the study.

ABSTRACT

This report presents the results of an ARINC Research Corporation analysis of procurement control for communications equipment. The AFSATCOM project was used as a case study to investigate the applicability of reliability incentives in such procurements. The value of IOT&E/DT&E data in substantiating specified requirements was also investigated.

SUMMARY

Several recent DoD procurements have used reliability-growth incentive provisions to motivate hardware contractors to develop and improve the operational MTBF of deployed equipment. Such incentives include:

- Reliability Improvement Warranties (RIW) for the AN/ARN-118(V) TACAN, being procured by ESD
- RIW and Target Logistics Support Cost (TLSC) goals for the F-16, being procured by ASD

However, there have been no specific studies of the applicability and implementation of reliability growth incentives for a communications system.

In the study reported on herein, the project team worked with the AFSATCOM DPML and ESD to investigate the selection and application of reliability-growth incentive options for that procurement and to assist in the development of a specific incentive. The team also studied the value of IOT&E/DT&E test data in assessing reliability characteristics of the AFSATCOM LRUs.

The study produced two kinds of conclusions -- those applicable to the AFSATCOM project specifically and those which appear to be applicable to a variety of equipments and procurement situations. The conclusions of general applicability are summarized as follows:

- There is no evidence of incompatibility between an RIW concept and a sole-source procurement.
- The development of an incentive such as RIW should begin at the same time full-scale development contracts begin.
- There is no evidence that any of five incentive plans investigated would not be applicable to communications equipment. However, each of the incentive plans is designed for a different goal, and these goals should be consistent with the procurement goals.

- It is important to coordinate the development of reliability incentives with all Air Force agencies and activities that may be affected by their implementation. In many cases, objections to or questions about incentives can be answered by providing a description of the requirements of the incentive.
- Data derived from IOT&E/DT&E tests may be useful in identifying serious reliability problems and for making a gross assessment of certain logistic support factors (such as initial spares requirements), but such data should not be used as a substitute for factory testing or reliability demonstration testing.

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CHAPTER ONE

INTRODUCTION

In February 1975, AFLC/AQ awarded ARINC Research Corporation a contract to perform a study of the applicability of reliability-growth incentives to Air Force communications equipment and to determine if DT&E (Development Test and Evaluation) and IOT&E (Initial Operational Test and Evaluation) testing could be used to derive reliability and maintainability information about a system. This final report presents the results of that study.

The approach to the investigation was to use the Air Force Satellite Communications (AFSATCOM) project as a case study. The objective of the AFSATCOM project is to provide the Air Force SIOP* force and other selected high-priority users with a highly reliable UHF satellite communications capability. The program consists of a space segment employing the Fleet Satellite Communications System (FLTSATCOM), the Air Force Satellite Data System (SDS), and other host satellites in conjunction with the terminal segment comprising airborne and ground terminals. These terminals, in turn, consist of the following two equipment groups:

- Group A - Terminal installation kits consisting of installation wiring, coaxial cables, mounting adapters, and miscellaneous hardware
- Group B - Terminals consisting of antennas, antenna mountings, antenna selectors, filter switches, message synchronizers, modems, system controls, preamplifiers, transceivers, I/O devices, and other specified LRUs

Various combinations of the Group B LRUs form a number of different terminal types. The terminals are used in both airline and ground installations. Any LRU type that is common to both airborne and ground terminals must be interchangeable; therefore, all such LRUs must be procured to satisfy both avionic and ground specifications. This report addresses the LRUs of the Group B equipment and the terminals in which they are used.

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*Single Integrated Operational Plan.

An analysis performed by the MITRE Corporation showed the life-cycle cost of AFSATCOM components to be very sensitive to the components' MTBFs. Such sensitivity is not unexpected since it has been observed often. Because of the potentially large number of equipments involved in the AFSATCOM procurement, the life-cycle-cost impact for MTBF values lower than specified was considered substantial, and the logistics manager (DPML) for the ground terminals recognized a need to take measures that would increase contractor attention to reliability and life-cycle costs.

At the time ARINC Research began work on the project, the AFSATCOM System Program Office (SPO) at AFSC/ESD was in the process of preparing an RFP for an initial production purchase. Prime-contracting competition had ended earlier with the termination of an RCA development effort. It was therefore necessary, in our consideration of incentives for reliability improvement, to recognize that the contractor, Collins Radio Group (CRG), would be bidding from a favorable sole-source position on any incentive options. We also recognized that since the RFP was nearing completion, there was insufficient time to develop an entirely new procurement concept for life-cycle-cost control.

Under our contract with the Air Force, we were to develop several candidate reliability-growth incentives, select the most appropriate one for the AFSATCOM program, and write the detailed terms and conditions for inclusion in the RFP. We were also tasked to review the IOT&E/DT&E test plans to determine their adequacy and the test data to judge the value of reliability information contained in such data.

The remaining chapters of this report present the results and findings of these tasks.

CHAPTER TWO

EVOLUTIONS OF THE RELIABILITY-GROWTH INCENTIVES

2.1 CANDIDATE CONTROL METHODS

In attempting to devise a method of controlling life-cycle costs for AFSATCOM components, we were operating under the constraints of severe time limitations and a noncompetitive procurement. The former constraint would preclude the development of novel control methods as well as any lengthy discourse or idea exchange with the contractor. The latter would require that the risks to the contractor be totally acceptable to Collins. Five candidate incentive plans were devised, any one of which could be made applicable to the AFSATCOM procurement. A brief description of their salient features is given in Table 2-1. They are described more fully in Appendix A, which also compares them on the basis of several rating factors.

Table 2-1. HIGHLIGHTS OF FIVE INCENTIVE PLANS FOR AFSATCOM

Plan	Features
1. Reliability Improvement Warranty (RIW)	Vendor repairs all failures of warranted equipment for fixed period of time at a fixed price. Vendor is motivated to minimize support costs by modifying equipments to improve reliability.
2. RIW with MTBF Guarantee (RIW/MTBFG)	The same incentives exist as under RIW. Also, if the vendor cannot attain the guaranteed reliability level, additional costs or penalties are borne by him.
3. Correction of Deficiencies (COD)	Vendor guarantees that the logistic support costs for his equipment will not exceed a certain target value. He uses his estimates of parameters in a prescribed logistic support formula to derive the target value.
4. Intensive Reliability Program (IRP)	Reliability is designed and built into the equipment through strong management and test programs.
5. Delayed Commitment (DC)	Allows a delay in exercising the RIW option until more accurate operational data are accumulated.

From a comparison of their attributes and based on program schedule considerations, it was concluded that the most desirable plans from the Air Force viewpoint would be, first, a combination of RIW with MTBF guarantee and, second, the RIW alone. The first of these controls represented the lowest risk in achieving the LCC controls and the highest contractor motivation for improving reliability. The second control was somewhat less desirable and any of the remaining three controls even less. It was decided to approach CRG directly with the RIW/MTBF and the RIW. The purpose of applying these controls would be to structure the details of the provisions so that both CRG and the Air Force would realize monetary benefits.

We believed that mutual benefits were achievable. Our approach, then, was to formulate a fundamental set of RIW/MTBF provisions and review them first with ESD and then with Collins. In the event that mutually acceptable terms and conditions could not be developed, the recourse would be to explore one of the three remaining controls. By late February, the first draft of a proposed set of RIW/MTBF provisions had been prepared, discussed with the ESD DPML, and sent to Collins for their review.

2.2 CONTRACTOR'S RESPONSE

In early March, ARINC Research met with members of the CRG project group to discuss their concerns and hear their assessment of the proposed RIW/MTBF provisions. The meeting began with a firm statement from CRG representatives that the MTBF Guarantee option would not be bid because the risk associated with an incorrect estimate of the AFSATCOM MTBF was too high.

The majority of CRG's comments on the RIW provisions were requests for clarification or minor changes. Among the requested changes were an incentive payment to CRG if they bettered the required turn-around repair time and a limit on the number of "no trouble found" LRUs processed without change in contract price.

Although there was not complete agreement on the RIW provisions as written, it was clear that a mutually acceptable set of terms and conditions was achievable. CRG, the Air Force, and ARINC Research reviewed the RIW document paragraph by paragraph. At the conclusion of the review, we had resolved all of the CRG concerns and had preserved the incentive aspects of the RIW. ARINC Research considered the Air Force position at the conclusion of the meeting to be favorable: CRG was apparently willing to bid on an RIW plan, making it unnecessary to pursue one of the three remaining, less desirable control methods. The final proposed RIW contractual provisions are presented in Appendix B. These provisions were presented to the ESD program office for distribution to interested commands and agencies and CRG; they were intended to evoke any additional dialog that was necessary for a complete understanding of all the logistic-support implications of the provisions. It was intended that the provisions be included as a part of the Air Force Statement of Work requirement to CRG in the RFP.

2.3 RESULTS OF ECONOMIC ANALYSIS AND ATTEMPTS TO PROMOTE RIW

Following the submission of the proposed RIW contractual provision, ARINC Research commenced work on an analysis to determine the economic appropriateness of procuring some of the AFSATCOM LRUs using RIW as a control. The results of that analysis and the recommendations derived therefrom are presented in Appendix C. Although the economic analysis points to a slight economic advantage for the RIW procurement, uncertainty in some of the input data values could reverse that advantage. A final judgment would have to be based on the contractor's prices.

While the economic analysis was under way, several concerns began to emerge regarding the acceptability of RIW for AFSATCOM. Notable among those reported were the following:

- SAC was very reluctant to give up organic maintenance. Under the RIW concept, intermediate and depot maintenance is performed by the contractor and it is he who gains maintenance experience and proficiency. The using commands naturally view this as a loss of self-sufficiency. The accomplishment of their missions is more vulnerable to the economic health of the RIW contractor, to strikes, and to other vagaries of civilian commerce over which they have no control.

- The other services were considering using AFSATCOM terminals and establishing common, tri-service support facilities. RIW support for the Air Force buy had an undetermined impact on these plans.

On 8 May 1975, appropriate Air Force agencies and commands were convened (the murder board) for a final review of the RFP Statement of Work. During this review it was decided that, in view of the RFP schedule, there was insufficient time to develop solutions to the foregoing problems. The proposed RIW provisions for AFSATCOM were deleted from the RFP.

CHAPTER THREE

RELIABILITY PROGRAM AND TEST DATA REVIEW

In the absence of a structured LCC control such as the proposed RIW and in view of the contractor's reluctance to bid on an MTBF guarantee, ARINC Research urged a renewed emphasis on other means of identifying, assessing, and correcting reliability problems. Two plans were implemented; the first was to review the adequacy of the reliability program being conducted by the contractor during development, and the second was to review the data collection plans and the data resulting from the combined IOT&E/DT&E* test program.

ARINC Research reviewed the reliability program requirements contained in the development RFP and found them to be well conceived and managed by the Air Force. We then reviewed the reliability and maintainability data collection procedures that were developed by AFTEC and were to be implemented during the IOT&E/DT&E. They were also judged satisfactory. No substantive changes were recommended for either the reliability program or the IOT&E/DT&E.

3.1 RESULTS OF SITE VISITS

To assess the effectiveness of the data collection called for in the IOT&E/DT&E test plans, ARINC Research engineers visited two AFSATCOM installations: airborne terminal 1A in the FB-111 at Plattsburgh, and ground terminal 9 at Verona. An account of the trip is contained in a special report included herein as Appendix D.

As a result of the trip, we reached the following conclusions:

- Emphasis at both sites was on performance.
- Reliability aspects of the IOT&E/DT&E would have to be given much greater attention if satisfactory reliability answers were to be produced.

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*In the interest of maintaining the tight program schedule, the Air Force combined the initial operational testing and the development testing into one test. The conclusions and recommendations of this report would remain unchanged if the tests had been conducted sequentially.

- The major source of reliability problems would probably lie in the areas of electromechanical components and maintenance-induced failures.

Our recommendations included several specific actions directed toward strengthening the IOT&E tests in the areas of R&M (see Appendix D).

In general, our observations made us doubt seriously that the test plan's reliability objectives would be adequately served, particularly if additional guidance to the test directors and attention to reliability were not given (see Appendix D). Our concerns were shared by the DPML and by several members of the test team. We requested and were granted permission to obtain copies of the reliability data forms prepared during IOT&E/DT&E for the purpose of assessing the reliability content of such data.

3.2 RESULTS OF DATA ASSESSMENT

The data assessment yielded specific conclusions concerning the AFSATCOM system and general conclusions regarding the applicability of IOT&E/DT&E data for reliability assessment. The conclusions are summarized in the following subsections (see Appendix E for a detailed treatment of the data assessment).

3.2.1 Specific AFSATCOM Conclusions

The following specific conclusions were derived from the data assessment:

- The data did not reveal any trends in common failure symptoms from one terminal to another.
- Individual terminals exhibited a wide range or dispersion of incident types without emphasis on a particular fault indication or LRU, with the exception of the ASR printers and the transmitter fault light.
- Evaluation of the data revealed a statistically significant increase in mean time between maintenance actions near the end of the test.
- At least half of the incidents described by the data were transient or intermittent anomalies for which no cause was found.
- The data could be useful in determining logistic-impact parameters, such as spares required.

3.2.2 General Conclusions

The observed characteristics of the AFSATCOM IOT&E/DT&E data lead to the general conclusion that it is difficult to substitute such data for reliability-test demonstration data. Dedicated spares, maintenance, and schedule resources are often not available to support detailed failure analysis and documentation of field faults. In addition, the IOT&E/DT&E tests are not conducive to the repeated trials that are sometimes necessary to reproduce a failure symptom or to the exhaustive testing sometimes required to confirm that a failure has been corrected. The different purposes that are intended to be served by reliability testing and by IOT&E/DT&E testing are probably most responsible for the inherent difficulties in using the latter test results to satisfy the former test requirements. Reliability-demonstration acceptance tests such as those described in MIL-STD-781 are intended as statistically based accept-reject tests. That we can use the data from such a test to make a point estimate of MTBF is not important to the decision to accept or reject the equipment. The tests are designed to accept (or reject) the equipment on the basis of a number of observed failures. The definition of "failure" is very important, and the classification of "incidents" that occur during the test as failures or nonfailures is often difficult and subject to interpretation even though such decisions are made by those trained to do so. It is not surprising, then, to encounter even greater difficulty in defining failures during IOT&E and DT&E. The personnel involved in such tests are apt to be operationally oriented, and this leads to an emphasis on equipment performance. For these reasons, it is concluded that IOT&E/DT&E data are not generally useful for reliability demonstration and that such use should not be attempted.

IOT&E/DT&E data are, however, useful for providing important logistics insight, as discussed in Section 3.2.1. They may also be used to identify the serious reliability problems such as in the AFSATCOM equipment, where problems were identified in the ASRs and with the transmitter fault light. (Other serious reliability problems were identified for the AFSATCOM, but not as a result of data analysis.)

CHAPTER FOUR

SUMMARY OF LESSONS LEARNED

The lessons learned in working with the AFSATCOM project office are believed to be applicable to a wide range of electronic equipment, including communications equipment. If fact, for the incentive concepts considered for AFSATCOM, once it is determined that the equipment can be maintained under a specific concept, e.g., RIW, much of the activity associated with subsequent efforts is procurement-oriented and less equipment-dependent. The lessons identified below should be applicable to future Air Force procurements that utilize any of the LCC controls that were studied for AFSATCOM. These lessons can be used as operating guidelines for such future procurements.

4.1 RIW AND THE SOLE-SOURCE PROCUREMENT

The AFSATCOM experience indicates that the RIW concept is not incompatible with a sole-source procurement. CRG expressed willingness to bid RIW for AFSATCOM. They were reluctant to bid an MTBF guarantee, and this reflects their hesitancy to accept the additional risk that such an option imposes on the contractor. However, the AFSATCOM lesson indicates that if a contractor is aware of his responsibilities under RIW, and equipment design and maturity are such that he can reasonably price his risks, he will accept an RIW in a sole-source environment. Because RIW was not included in the final RFP that went to CRG, it is impossible to know what their price for such requirements would have been. However, it is clear that they were willing to consider such requirements in bidding on the RFP.

4.2 TIME REQUIREMENTS FOR DEVELOPMENT OF INCENTIVE OPTIONS

A primary reason for selecting RIW for inclusion in the AFSATCOM RFP was that the time available for developing terms and conditions was short. CRG was familar with the RIW concept since at the time of the AFSATCOM effort, the same operating division at Cedar Rapids was involved in a full-scale development program for the AN/ARN-XXX TACAN. Thus CRG's AFSATCOM program manager and his team were in communication with personnel in the Collins TACAN program who were discussing similar requirements for that equipment. Thus Collins was in an excellent position to understand

the risks and responsibilities involved in RIW. Had another contractor been involved in the AFSATCOM effort, it might not have been possible to develop and implement the RIW option in the time available.

For any of the reliability-growth incentives studied during this effort, it is important that the contractors who are required to bid on such incentives have a complete understanding of their responsibilities and risks. This includes an understanding of the purposes and goals of the incentive, the contractual requirements to be imposed on the contractor, and the interfacing requirements that the incentives impose upon the service. Unless such understanding can be developed with the contractors, serious bidding errors may occur.

For these reasons, it is important to begin the development of incentives well in advance of any actual issue date for an RFP. In fact, incentive development in coordination with contractors should begin at the same time full-scale development contracts begin so that contractors will be allowed to design their equipment to meet the incentive requirements.

4.3 APPLICABILITY OF VARIOUS INCENTIVE OPTIONS

Each of the reliability-growth options examined for the AFSATCOM equipment appears to be applicable to a wide range of electronic communications equipment procurements. Basically, the incentives fall in two categories:

a. RIW, RIW/MTBFG, etc., wherein failed units must be returned to the contractor for repair.

b. The COD, wherein field measurements of various reliability and logistics parameters will be made to compute a measured logistics support cost. In this situation, ordinary in-service maintenance will be in effect for the equipment.

The goals of the various options studied for AFSATCOM also differ to some extent, and these differences should be considered if the incentive approach is to be used in subsequent procurements. For example, RIW is designed to motivate the contractor to repair and return assets in a minimum time. The impact of RIW on reliability is only indirect -- improvements will be incorporated if the contractor believes he can profit from such improvements. The RIW/MTBFG is designed to set a numerical requirement for MTBF, which the contractor is motivated to meet. The COD incentive is designed to be used when the military interest is centered on controlling LCC rather than reliability or a specific logistic support factor.

Finally, the Air Force requirements to implement the various incentive options studied for AFSATCOM are different but fall into two categories corresponding to a and b above:

a. Tracking of assets and MTBF or other reliability parameter measurements when the repairs are made by the contractor

b. Development of verification test plans when COD and MLSC measurements are to be made

In developing any of the options studied for AFSATCOM, careful attention must be paid to these implementation problems before RFP release. Otherwise, major implementation problems can develop that will affect the Government-contractor agreements.

4.4 INTEGRATION OF INCENTIVES WITH PROGRAM EFFORT

As in the AFSATCOM experience, incentive programs that involve departures from the normal Air Force maintenance support concept may have an impact on many Air Force agencies and activities. It is therefore extremely important to begin making incentive arrangements early in the equipment development phase and to coordinate there arrangements with the other activities being conducted during this phase. In many cases, objectives to questions about incentives can be answered quite simply by describing the requirements of the incentive. Misunderstandings about the goals and implementation of an incentive quite often lead to confusion about the incentive itself.

Also, as mentioned above, incentive plans should be devised early in the full-scale development phase, if at all possible, in order to allow the contractors to design equipment that will meet incentive goals. For example, under RIW, contractors are very likely to design internal test points and test procedures different from those they would design under a COD, wherein the maintenance will be performed by Air Force personnel.

4.5 THE VALUE OF DT&E/IOT&E DATA FOR RELIABILITY ASSESSMENT

The purpose of the Reliability/Maintainability Plan to be implemented during IOT&E/DT&E testing was to give further assurance that the R/M requirements of the AFSATCOM specification would be met in operational use and to provide further information on which to base a production decision. ARINC Research was asked to analyze the test data for the additional purpose of assessing the value of these data as a substitute for factory testing, including demonstration testing.

The DT&E/IOT&E data characteristics discussed in Appendix E are probably typical of such data. They lead to the general conclusion that it is difficult to substitute such data for reliability-test demonstration data. Dedicated spares, maintenance, and schedule resources

are often not available to support detailed failure analysis and documentation of field faults. The difficulties encountered in using DT&E/IOT&E data to satisfy reliability test requirements stem from the different purposes for which reliability testing and IOT&E and DT&E testing were designed. The personnel involved in such tests are apt to be operationally oriented, and this leads to an emphasis on equipment performance. For these reasons, it is concluded that DT&E/IOT&E data are not generally useful for reliability demonstration and that such use should not be attempted.

From analysis of the IOT&E/DT&E data, we were able to conclude that such data are useful for providing important logistics insight, as discussed previously under specific AFSATCOM conclusions. They may also be used to identify the most serious reliability problems.

APPENDIX A

COMPARISON OF METHODS FOR CONTROLLING LOGISTIC SUPPORT COSTS

1. BACKGROUND

The approach taken to develop a suitable reliability incentive (control) plan for the AFSATCOM procurement was to devise several candidate plans, any one or combination of which would be suitable for AFSATCOM; evaluate the intrinsic characteristics of the plans; and then select no more than two for further detailed development. This appendix describes the approach taken and the results of the selection process.

2. SELECTION OF CANDIDATE CONTROL PLANS

The recent successful application of options for a Reliability Improvement Warranty (RIW), an MTBF guarantee (MTBFG), and a Correction of Deficiencies (COD) provision in two large Air Force contracts -- AN/ARN-118(V) and F-16 -- led ARINC Research to select these same candidates for AFSATCOM. They all had the advantage of having been fully and recently developed, an important consideration in view of the limited time available for incorporating an acceptable plan in the RFP.

Since much of the AFSATCOM would be developmental, resulting in higher risks associated with MTBF estimates, ARINC Research added a plan that would allow the contractor the benefit of some test data. The plan, called a Delayed Commitment (DC), would incorporate the essence of the RIW and MTBFG, but the price would not be fixed until CRG had gained test experience. Still another plan, the Intensive Reliability Program (IRP), applied in conjunction with an RIW would incorporate the elements of a MIL-STD-785 program but would receive a high level of management attention.

3. DISCUSSION OF INCENTIVE OPTIONS

3.1 Reliability Improvement Warranty

The RIW approach features an incentive strategy by which the vendor is motivated to minimize support costs by modifying equipments to improve reliability. In an RIW the vendor corrects all failures of those items

under warranty. The RIW price is fixed at the time a production contract is awarded. If reliability is poor, the vendor experiences higher repair costs. No explicit level of MTBF is written into the warranty. Incentive is based on the profit motive. Under the RIW option, there will probably be vendor repair of both LRUs and SRUs. Military maintenance is limited to on-equipment removal and replacement of LRUs.

3.2 RIW with MTBF Guarantee

Under the Reliability Improvement Warranty with a Guaranteed MTBF, the same incentives exist as under the RIW. In addition, if the vendor cannot attain the guaranteed reliability level, additional costs or penalties are borne by him. Since the level of achievement is explicit, the vendor must meet the goal in addition to simply balancing repair and modification costs. As a result, RIW/MTBF gives the user greater control over life-cycle costs and at the same time increases vendor risks. Since this type of warranty is somewhat more complex, there is additional difficulty in administering it, primarily in reliability data management and analysis. Warranty costs as a result of the foregoing considerations are usually greater. The level and type of services required are comparable to those of the RIW, with the possibility that some additional logistics assets will have to be provided by the contractor.

3.3 Correction of Deficiencies

For the COD option, the contractor must guarantee that the logistic support costs for his equipment will not exceed a certain Target Logistic Support Cost (TLSC). He uses his estimates of parameters in a prescribed logistic support cost formula to derive the TLSC. After the system becomes operational, the parameters are measured under field conditions and the same formula is used to compute the measured logistic support cost (MLSC). If the MLSC exceeds the TLSC, a deficient condition is considered to exist and the contractor must correct deficiencies. If the MLSC does not exceed the TLSC, the contractor is awarded a fee. The cost of correcting deficiencies may be shared or may be borne entirely by the contractor. Administrative difficulties and enforceability risks may vary depending on the complexity of the COD provisions.

3.4 The Intensive Reliability Program and Delayed Commitment Concepts

There are two derivatives of the three reliability incentive options. One of these concepts is the adoption of an intensive reliability program (IRP) in conjunction with the RIW. Reliability is designed and built into the equipment through strong management and test programs. It is extremely difficult to control reliability downstream in the equipment life cycle. Even though severe penalties may be imposed upon a vendor, discovery and verification of inadequate reliability during operational usage inevitably leads to delays, disputes, and excessive operational and ECP costs. Adequate reliability may be unattainable in some cases without radical redesign.

Table A-1. COMPARISON OF METHODS FOR CONTROLLING LOGISTIC SUPPORT COSTS

Factors	RIW	RIW/MTBF	COD	DC	IRP (Implemented with Warranty)
1. AF Logistic Costs Control Risk	Moderate	Low	High	Low (post delay)	Low
2. Contractor Pricing Risk	Moderate	High	Moderate	Low	Low
3. Administration Difficulty	Moderate	High	Low to moderate	Variable depending on warranty selected	High
4. Enforceability Risk	Moderate	Moderate	Moderate to high	Variable depending on warranty selected	Low
5. Contractor Reliability-Growth Motivation	Moderate	High	Moderate	Variable	High
6. Commitment Time	Start of Production	Start of Production	After Follow-On OP Test	Variable with delay in commitment	Between beginning of engineering development and end of production
7. Services Provided	Depot and partial field maintenance plus no-cost ECPs	Depot and partial field maintenance, logistics assets if required, plus no-cost ECPs	Possible logistics assets if required, or equipment ECPs	Vendor performs maintenance at cost during delay period	Provides high-quality technical-service benefits in all phases
8. Cost Experience (Average per Unit)	4 to 7% of acquisition cost per year	5 to 9% of acquisition cost per year	0 to 16% of acquisition cost per year	--	--

An intensive reliability program starting with design inception and maintained through production and into operational periods is of great benefit. All programs provide some measure of reliability. An intensive program, however, encompasses all design aspects, tests, selection of components, production methods, environmental and profile usage, and strong management and monitoring structures to avoid problems. Such an intensive program implies technical services and costs over and above those of a normal reliability program. Before a commitment to an IRP is made, economic analyses should indicate that the costs will be recovered through reduced O&M costs.

Another concept to be considered in selecting an option is the delayed commitment (DC). Under a DC concept, an RIW option would not be exercised until a period of time elapsed over which operational experience could be accumulated concerning the level of reliability of the equipment. Thus, after a year or two of close observation, a warranty could be imposed on the basis of more accurate information. As a result, life-cycle costs, warranty pricing, and risks could be more accurately assessed. One difficulty with the delayed commitment is in structuring the procurement so that the RIW price is not based solely on a poor MTBF if such is observed during the trial operational period.

Logistic support during the trial operational period could probably best be handled on a time and material contracting basis.

Both the intensive reliability and delayed commitment concepts should be kept in mind when warranty options are being compared. Both approaches offer relatively low vendor cost-control risks except for the short interim period under delayed commitment. In the latter variation, it is assumed that increased technical knowledge acquired over the delay will balance future difficulties. Risks associated with the adoption of these two concepts are also low for the vendor for the same reasons. Administrative difficulties may be high or variable (depending on the warranty option eventually chosen). An IRP requires greater technical services and follow-through, together with more paper work and analysis. If an IRP concept is followed, enforceability risks are assumed to be minimal since an intensive reliability program will be required. Under the DC concept, reliability-growth motivation will depend on the reliability assessment made during the delay period and the eventual incentive details selected. In the IRP approach, it is assumed that the initial reliability level is improved as a result of an intensive program.

4. COMPARATIVE ANALYSIS

Each of the incentive options described in the preceding section was evaluated on the basis of several factors or characteristics believed to be important selection criteria. Table A-1 summarizes the results of these evaluations. In most cases, the criteria were scored as low, moderate, or high -- referring only to the relative standing of the listed options. The criteria are explained in the following paragraphs.

4.1 AF Logistic Cost-Control Risk

The relative cost control risk of each option for the user (USAF) encompasses all costs associated with acquisition and ownership over the life cycle. A grade of *high* indicates a greater probability that excessive or unmanageable costs will develop with the particular selection. A *low* grade indicates a lower probability of experiencing excessive costs. The assumption underlying each classification is that each option provides a greater or lesser degree of control over costs.

4.2 Contractor Pricing Risk

Contractor pricing risk is the risk (or probability) the contractor must confront when he prices services and material costs incurred under the incentive options. A *high* risk indicates that the contractor has less knowledge or control over factors that influence the costs of satisfying the incentive option.

4.3 Administration Difficulty

Various degrees of difficulty -- associated with either administrative costs or the mechanics of implementation -- may be experienced in administering the different options. A *low* grade indicates relatively little difficulty in this regard.

4.4 Enforceability Risk

With each option, there may be varying degrees of difficulty in enforcing the provisions of the incentive option. A *low* grade indicates that relatively little risk will be encountered in enforcing the incentive provisions.

4.5 Reliability-Growth Motivation

As a result of an incentive provision, there is some confidence that reliability growth will be provided by each option type. RIW/MTBF, for example, is graded as *high* because it encompasses the economic incentives for improving reliability and a clearly defined or guaranteed level of achievement.

4.6 Commitment Time

Commitment is the earliest point in the LRU life cycle at which the incentive option could be implemented. Grades for this factor are simply stated as points in the life cycle of the units.

4.7 Services Provided

Services provided are associated with either the level of maintenance support expected under each option or salient contractural procedures, e.g., "No Cost ECPs".

4.8 Cost Experience

The estimated additional LRU cost expected to be incurred under each option is also noted in the comparative summary. These figures are based on actual F16 bid prices.

5. SELECTION OF CONTROL PLANS FOR AFSATCOM RFP

Both the Delayed Commitment plan and the Intensive Reliability Program plan required considerable additional development work with both the contractor and the Air Force. Since the RFP preparation was nearing completion, both of these plans were abandoned. Of the remaining three, the comparative evaluation shown in Table A-1 shows the RIW and the RIW/MTBFG to be equal or superior to the COD. These two plans were therefore selected for the RFP.

APPENDIX B

RELIABILITY WARRANTY PROVISIONS

PART I - Statement of Contractor Warranty

1. The contractor warrants that each AFSATCOM terminal LRU identified in * furnished under this contract or under an associated separate spares contract will be free from defects in design, material and workmanship and will operate in its intended environment in accordance with contractual specifications, for the warranty period set forth herein as it may be extended under the provisions hereof.

2. Any LRU that fails to meet the aforesaid warranty and is returned to the contractor's plant or designated repair facility at government expense shall be repaired or replaced, at the contractor's sole option and expense, so as to operate in accordance with contractual specifications as demonstrated by a mutually acceptable repair test procedure.**

3. The contractor shall not be obligated to repair or replace at no cost to the government any LRU warranted hereunder for loss, damage, or nonconformance by reason of fire, explosion, submersion, acts of God, such as flood hurricane, tornado, earthquake, lightning, etc., aircraft crash, enemy combat action, or tampering by government personnel, provided there is clear and convincing evidence of such cause unless such loss or damage occurs on premises owned or controlled by the contractor or unless the occurrence of fire or explosion was a result of non-conformance of the warranted LRU. In addition, the contractor shall not be obligated under these warranty provisions for

(a) repair of external physical damage caused by accidental or willful mistreatment by non-contractor personnel

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* Appropriate reference to list of LRU's to be covered by this warranty.
** Specification and repair test procedures to be set forth in definitive contract.

(b) repair of internal physical damage which, in the determination of the government, has been caused by accompanying external physical damage due to mistreatment or tampering by non-contractor personnel.

The conditions specified above, except acts of God, apply only to loss and damages occurring on locations other than those owned and controlled by the Contractor or occurring while the LRU is not under the Contractor's possession or custody.

There is a presumption that a warranted LRU returned to the contractor's repair facility during the warranty period is covered under this warranty and that only the exclusions listed above shall void the contractor's responsibility to test, repair or replace at no increase in contract price under this warranty. There is no distinction to be drawn between type of failure such as relevant versus non-relevant or verified failure versus no-defect found provided that the number of no-defect found cases in a six-month period do not exceed an amount given by the following formula:

No-defect found limit = Total number of all items returned for repair during the six-month period times 0.3

The contractor will be reimbursed at a fixed rate of ________ per return for no defect found cases during the period in excess of the defined limit.

The Administrative Contracting Officer (ACO) shall promptly determine whether any of the above exclusions apply to a returned LRU upon receipt of the contractor's claim accompanied by clear and convincing evidence.

4. Nothwithstanding the provisions of the "Inspection" (1969 May) Clause (ASPR 7-103.5(a)) regarding the conclusiveness of acceptance and the waiver of defects which are susceptible to discovery prior to acceptance, the contractor shall be obligated to repair or replace any defective LRU accordance with the terms and conditions of this warranty. The rights and obligations of the parties under this warranty are in addition to and independent of the rights and obligations of the parties under the other provisions of this contract. Except as provided by the general provision of this contract

entitled "Inspection," the contractor's obligations and the government's remedies for repair and replacement of nonconforming LRU's are solely and exclusively as stated herein. In no event shall the contractor be liable for special consequential or incidental damages.

5. For all warranted LRUs, the initial warranty period shall start upon final government acceptance of the first production terminal and shall extend for a period of ___ months from 31 December of the calendar year in which the first production terminal was finally accepted by the government, or until a total of __________ hours of terminal operation are accumulated on all operational terminals, whichever occurs first.

6. For purposes of this warranty, the initial anniversary date shall be defined as one year after government final acceptance of the first production terminal. Reporting periods and various measurement/adjustments associated with the warranty are based on this initial anniversary date.

PART II - Contractor Obligations

1. All contractor developed and initiated ECPs for improved reliability or maintainability of the modules which are approved by the government shall be incorporated at no change in contract price. The contractor shall maintain configuration control by serial number. All changes to configuration, design, part, T.O., AGE, etc., that affect form, fit and/or function of the LRU shall be submitted to the contracting officer for approval. Changes not affecting form, fit and/or function shall be documented, accomplished and reported to the Air Force. As each item is repaired by the contractor, it shall be brought up to the latest approved configuration, or at the contractor's option the changes may be implemented by the contractor immediately on Air Force sites provided they are on a non-interference basis. It is intended that at the end of the warranty period all LRUs shall be in the latest configuration. Except for Class II changes, those items in the inventory not in the latest configuration shall be modified by the Air Force using kits and T.O.s supplied by the contractor under these reliability improvement warranty provisions. The kits and T.O.s referred to above shall

be supplied by the contractor within 180 days following the end of the warranty period as a part of these reliability improvement warranty provisions and at no change in the price fixed for such warranty. The contractor shall perform modifications which are not kitable for those items in the inventory not in the latest configuration during the period of 180 days following the end of the warranty period as a part of these warranty provisions and at no change in the price fixed for the warranty. Modifications to those items not completed during this 180 day period became the responsibility of the Air Force, provided that said items were not delivered to the contractor for modification prior to 15 days before the end of the 180 day period.

2. The contractor shall cause a suitable and prominent display of the warranty period information in form and content satisfactory to the contracting officer in addition to the standard identification plate, to be placed on the surface(s) of the LRU to insure reasonable visibility when removed. Within 120 days after receipt of award of Contract ___________, the contractor shall submit to the contracting officer for approval, the proposed wording, content material and placement of this information.

3. The contractor shall maintain throughout the warranty period a fully operational warranty repair facility located at the *production facility*. The locations of additional repair facilities shall be subject to the approval of the government. The contractor shall also maintain at each repair facility a secure storage area (i.e., bonded storeroom) for government owned spare and repaired LRU's. Property control of any returned LRU's will be in accordance with the ASPR Appendix B, 'Manual for Control of Government Owned Property in Possession of Contractors."

4. The contractor shall provide and install seals for all warranted LRUs to minimize unauthorized maintenance. The design of the seals should be such that inadvertent seal breaking is minimized and that breaking of a seal through tampering is evident.

5. (a) In the event of a failure of a warranted LRU, the government shall promptly notify the contractor in writing or by electronic message (e.g., TWX)of said failure and the serial number of the LRU involved . whenever possible.

(b) Upon receipt of such notification, the contractor shall package and ship a replacement government-owned LRU from the secure storage area to the appropriate government facility. To the extent possible, a first-in/first-out basis shall be used in selecting units for shipments from the storage area. Such shipment shall be made within one working day from the time of receipt of notification, but in no event shall such shipment be made later than 72 hours after receipt of notification. Preservation, packing and packaging shall be in accordance with Section __ of the Schedule of this contract. For shipment the contractor shall use a Government Bill of Lading (GBL) accompanied by a DD Form 1149 for transfer of government property accountability. In the event that spares in the secure storage area are insufficient to meet demand, the contractor shall follow a shipping-priority system at the direction of the contracting officer.

6. Within an average of 15 calendar days from receipt of a returned LRU for which this warranty is in force, the contractor shall correct, replace or install approved modifications in such items as necessary and store the items in the secure storage area. This turnaround time requirement shall apply to all LRU's returned except those to which one or more of the exclusions listed in Part I, paragraph 3 apply. The contractor shall not be liable for any time delays if the failure to perform the contract arises out of causes beyond the control and without the fault or negligence of the contractor. Such causes may include, but are not restricted to, acts of God or of the public enemy, floods, epidemics, quarantine restrictions, strikes, freight embargoes, and unusually severe weather; but in every case the failure to perform must be beyond the control and without the fault or negligence of the contractor.

7. Calculation of average turnaround shall be made over six-month periods for each LRU type. The first such period shall start six months prior to the initial anniversary date, and subsequent six-month periods shall follow consecutively until warranty termination. If the average turnaround time in a six-month period for an LRU type is greater than 15 days, as computed from warranty data records, the contractor will be required to lend the Government spare LRU's in accordance with the following formula:

$$n = \frac{(4\ NT_A + 24\ NT_G)(\overline{T} - T^*)}{(MTBF)\ (2YW-1)} - L_G \quad \text{(rounded to next highest integer)}$$

where: n = number of spares to be furnished

NT_A = the average number of applications of the LRU type in airborne terminals during the six-month measurement period

NT_G = the average number of applications of the LRU type in ground terminals during the six-month measurement period

MTBF = the specified mean time between failures for the LRU type in hours

YW = the warranty period in years

L_G = spares of the LRU type previously consigned to the Government for failure to meet the turn-around requirement

T^* = the required turn-around time (15 days)

$\overline{T}$ = the average turn-around time in days of all the returned LRU's (by LRU type) during the six-month period calculated to three decimal places.

If n is positive, the contractor shall provide such consignment spares to the Government within 45 days if the contractor is currently producing such units, or within 120 days if the units are not currently in production. If n is negative, the Government shall return any consignment spares of the LRU type within its inventory within 45 days up to an amount equal to the absolute value of n. The Government shall purchase any consignment spares not returned within the required 45 day period. If the absolute value of n exceeds the number of consignment spares and n is negative, the Government shall pay the contractor within 45 days an amount equal to the following formula:

$$\text{Amount} = .5\ (\ |n| - L_G)\ \ (\text{UCOS})$$

where UCOS is the last production price of the LRU type.

8. The contractor shall maintain records by serial number for each LRU under warranty as required in Part V hereunder. Upon request, these records and associated data and documentation shall be made available to the Government at the contractor's plant during the warranty period for period for review of their adequacy and accuracy.

9. The contractor shall place those warranty provisions applicable to using activities in all pertinent Technical Manuals under this contract.

10. The contractor shall have a continuing responsibility to accept for correction or ECP installation and to complete the correction or ECP installation of, or furnish a replacement for, any item shipped to the contractor's repair facility with a shipping date on or before the last day of the warranty period as extended, notwithstanding any other provisions of this warranty.

PART III - Government Obligation

1. The government shall

a. To the extent practicable, verify the failure using appropriate procedures and test equipment.

b. Furnish to the contractor, with each returned LRU to the extent possible, complete failure-circumstance data and test readings, correctly recorded on AFTO 350 or equivalent.

c. Utilize, to the extent practicable, packing and packaging per MIL-STD-794 for all shipments of the LRUs, and include a proper transfer of custody form (DD Form 1149).

d. Promptly ship each nonconforming LRU to the contractor.

e. Notify the contractor of defects, deficiencies or non-conformance of an item and provide shipping instructions for delivery of a replacement LRU. (See Part II, paragraph 5a).

2. In recognition of the high contractor motivation for total cost control effected through these warranty provisions, the government agrees that all no-cost ECPs submitted in accordance with MIL-STD-480 to improve

reliability and maintainability for the units will receive special, expeditious processing. Notwithstanding this special processing, any such ECP shall be formally incorporated in the contract by the government 35 days after receipt by the PCO unless the contractor has received written notification of its non-approval from the government prior to that date.

PART IV - Miscellaneous

1. Any LRU returned to the contractor for which he does not have the responsibility to repair or replace under the terms of this warranty shall be repaired, replaced or disposed of as directed by the Administrative Contracting Officer. Any actions taken by the contractor at the direction of this ACO under this subparagraph shall be compensated for by separate equitable price/cost adjustment negotiated between the contractor and the ACO. Such equitable adjustment shall also consider any credits due the government.

2. An LRU returned to the contractor for repair or replacement hereunder, upon return to the government shall have applicable thereto the balance of the warranty period.

3. The contractor shall be permitted to retain any LRUs he replaces, or materials removed from ones repaired, which are replaced or repaired pursuant to his obligations under this reliability improvement warranty. Disposition of or LRUs not covered by this warranty shall be pursuant to directions issued by the ACO.

4. The government shall not provide new (i.e., additional) facilities, tooling or equipment of any type for contractor performance under this warranty.

PART V - Warranty Data Requirements

The contractor shall develop and maintain a data accumulation, processing, analysis and reporting system capable of providing the data items necessary for implementing any of the provisions of this warranty, and capable of providing to the government data and information on the reliability and maintainability of the warranted LRUs and the effectiveness of the warranty procurement concept. All data required herein shall be made available to the government at the contractor's plant upon request

during the warranty period. The government will provide, to the extent possible, applicable maintenance and utilization data to the extent generated by the Air Force 66-1 Data System.

2. The contractor shall establish and maintain records of each returned LRU consisting of the following data items:

a. Date received by contractor
b. Serial number
c. ETI reading (if applicable)
d. Condition of unit based on initial inspection
e. Failure mode
f. Probable failure cause
g. Action taken for repair
h. Manhours expended by labor category
i. Parts and material usage
j. Test results
k. Date stored in secure storage area
l. Summary data on No-Defect-Found occurrences

3. The contractor shall provide a semi-annual Warranty Data Report covering warranty experience over each six-month reporting period. However, the first such report shall cover all warranty experience up to the initial anniversary date (as defined in Part I, paragraph 7). Such reports shall be delivered to the government within 60 days from the end of the reporting period. This report shall, at a minimum, contain the following:

a. LRU Initial Delivery: a record, by serial number of each LRU showing ETI, date of shipment, and shipping destination.

b. Corrective Action Summary: a record by serial number of corrective actions of LRUs showing originating field activity (if available), ETI reading, date of receipt, contractor corrective action, warranty coverage applicability, manhours expended by labor category, parts and material costs and date of repair completion.

c. Secure Storage Area Population: a listing of the number of each type of LRU in the secure storage area at the end of each month in the reporting period.

d. Unit Cycle Time: to the extent practicable, a summary and anlaysis of the number of days for the major elements of the maintenance

cycle as follows:

Contractor receipt

to

Storage in secure storage area

to

Shipment to Government activity

to

Installation in AFSATCOM terminal

to

Removal from terminal

to

Shipmment to contractor

to

Receipt by contractor

e. LRU Reliability: analysis of causes, modes, trends, and patterns of field failures and actions taken, recommended, or projected for corrective action. To the extent possible, the effects of varying field environment on operational reliability shall be investigated.

f. Modification Status Summary: a summary of modifications recommended and incorporated by the contractor for reliability/maintainability improvement and a record by serial number of the modification status of each delivered LRU.

g. Warranty Population: a monthly summary of the number of LRUs known to be in the Government inventory under warranty, listed according to the amount of remaining warranty period. Information concerning lost LRUs or LRUs declared nonrepairable should also be summarized.

h. Turnaround Time Statistics: a record of measurements and calculations necessary for implementing the provisions pertaining to the turnaround time requirement as specified in Part II, paragraphs 6 and 7.

i. Other pertinent data, facts, information, and investigations that the contractor, at his discretion, believes will be of value to the Government in implementing and expanding the RIW concepts.

5. A data collection, analysis, and reporting plan shall be submitted 120 days after the effective date of the contract, detailing the data records to be maintained and the report format to be provided for the Warranty Data Report.

Reports shall be delivered to the PCO for final acceptance.

APPENDIX C

RESULTS OF ECONOMIC ANALYSES

1. INTRODUCTION

As part of this contract effort, ARINC Research performed an economic analysis on some selected LRUs to determine the appropriateness of procuring these LRUs under warranty conditions for some specified time period to be determined by the analysis. The maintenance concept assumed for all candidate LRUs under organic maintenance was that of module replacement at the shop level and module repair at the depot level for the repairable modules. For the warranty case, it was assumed that the module replacement and repair were accomplished by the vendor.

Since there is a possibility that AGE would be procured even in the warranty case, two analyses were performed -- one assuming AGE procurement and one assuming no AGE procurement until transition to organic maintenance.

2. SELECTION OF LRUs

On the basis of a MITRE study covering the full deployment of the systems, the 15 LRUs with the highest estimated life-cycle costs were selected for analysis as possible candidates for procurement under warranty conditions for the first buy of systems, although only 12 were to be procured for the first buy. However, it was considered necessary to apply some equipment and application criteria to these LRUs before proceeding with the economic analysis.

The following major equipment factors were used as selection criteria:

- Appropriate level of equipment maturity. Warranty should not be used for items that are considered to be developmental. Conversely, for very mature items, warranty may not offer the proper incentive. Warranty is intended for proven designs (nonexperimental) that are entering full-scale production. Through warranty, feedback is provided to the contractor to achieve stated reliability levels through an improvement or growth process. A very mature design, which has undergone such growth, may not be a candidate for cost-effective warranty application.

- Field-testability of unit. Since most warranties will require return of the failed unit to the vendor, it is important that the unit be field-testable to determine its state accurately. The inability to field-test can greatly increase the cost of support because additional pipeline spares are required and the contractor has the added expense of testing the good item.

- Proper marking or labeling of unit. The most effective means of communicating the existence of warranty coverage is suitable marking of the item itself. Items that cannot be suitably marked, because they are too small or have highly irregular external surfaces are not considered good candidates for warranty coverage.

The following major application factors were used as selection criteria:

- The environment, operational reliability, and maintainability are known or predictable. For effective evaluation and pricing of his warranty liability, the contractor must have information on the expected use environment, equipment operating time, expected number of failures, and maintainability from which to determine expected repair costs. Too much uncertainty in such estimation may expose the contractor to undue risks. For example, designs containing a significant quantity of new part types, for which there is no method of predicting reliability, may not be good candidates.

- Unit reliability and usage levels are amenable to warranty maintenance. Units that are highly reliable may not fail often enough to justify a warranty procurement, especially if the government already has repair capability. Similarly, if the reliability/ operational usage level is such that a large number of failures occur, the cost of spares required to maintain the pipeline to the contractor's plant as compared with the cost of on-site field repair may make warranty support uneconomical. Equipments that remain dormant for long periods and have limited shelf life may not receive sufficient exposure to make warranty worthwhile.

The available information on the selected candidates did not violate the foregoing criteria. Therefore, further analysis was undertaken to determine if it would be economically advantageous to use warranty conditions in procurement.

3. DISTRIBUTIONS OF TERMINALS AND LRUs

For the first-buy analysis, a total of four airborne and thirteen ground terminal types were considered.

In order to compute the correct sparing requirements for each LRU type, it was necessary to ascertain the numbers of installed LRUs of each type located at each site. However, some of the same LRUs are used in

different types of terminals, and in a number of instances more than one type of airborne terminal was located at the same site, e.g., one type 1 and one type 2 at one site; or one type 1 and two type 2's at another site.

Table C-1 lists 22 such site configurations of terminal types. They are grouped according to whether the terminal is a ground type or airborne type. The airborne terminal types are further grouped according to whether there is only one type or more than one type at a site.

In addition to the number of LRUs of each type installed at each of the bases, it is also necessary to know the monthly operate hours for each of these installed LRUs in order to compute the correct spares requirement. Table C-2 provides the information needed to calculate the total operate hours for each LRU type at each of the sites at which one or more of that type is installed.

4. EVALUATION OF REQUIRED BASE AND DEPOT TEST EQUIPMENT

The determination of AFSATCOM test equipment costs for use in the RIW economic analysis was complicated by the following factors:

- It was desirable to perform an economic analysis on an LRU-by-LRU basis; thus the test equipment cost had to be allocated in some way to the LRUs.
- Common test equipment was used on different LRU types.
- Some LRUs using common test equipment were located at the same sites and some at different sites.

The following steps were used in deriving the test equipment cost for each LRU type.

Step 1. Group the LRUs under study into similar functions (Columns 1 and 2, Table C-3).

Step 2. Order the LRU groupings by criteria supplied by the Air Force. (Ordering of the LRU groupings was necessary so that test equipment costs common to more than one grouping would not be considered more than once.)

Step 3. For each LRU in each grouping, identify the specific pieces of test equipment, and their cost*, required to repair that LRU.

Step 4. Within each LRU grouping, identify those pieces of test equipment that are used for more than one LRU in the group.

Step 5. For each LRU, add the costs for test equipment identified in Step 4.

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*Costs were taken from a MITRE LCC study.

Table C-1. DISTRIBUTION OF LRUs WITHIN TERMINAL TYPES													
Site Configuration Number	Terminal Types in Configuration	Number of LRUs by LRU Type											
		Type 23	Type 18	Type 16	Type 19	Type 30	Type 20	Type 12	Type 28	Type 21	Type 44	Type 11	Type 35
Airborne (One Type per Site)													
1	1	1	0	1	0	0	1	0	0	0	2	1	1
2	1A	1	0	1	0	0	0	0	0	0	2	1	1
3	2	1	0	1	0	0	0	0	0	0	1	1	0
4	3	2	5	0	2	1	0	5	1	1	4	0	0
Airborne (More Than One Type per Site)													
5	1 and 2	2	0	2	0	0	1	0	0	0	3	2	1
6	1 and 2	3	0	3	0	0	1	0	0	0	4	3	1
7	1 and 3	24	15	18	6	3	18	15	3	3	48	18	18
8	1 and 3	5	5	3	2	1	3	5	1	1	10	3	3
9	1, 2, and 3	44	40	28	16	8	14	40	8	8	88	28	28
Ground (One Type per Site)													
10	8A	0	4	0	0	1	2	4	0	0	0	0	0
11	C1	0	20	0	8	2	0	20	0	4	0	0	0
12	C3	0	2	0	2	1	0	4	0	0	0	0	0
13	C9	0	6	0	4	1	0	10	0	2	0	0	0
14	E12	0	4	0	2	1	0	6	0	2	0	0	0
15	P8	0	10	0	4	1	0	10	0	1	0	0	0
16	P11	0	1	0	0	0	0	1	0	0	0	0	0
17	E3	0	3	2	2	1	0	5	0	1	0	0	0
18	5D	0	2	0	0	0	0	2	0	0	0	0	0
19	14B	0	10	0	4	1	0	10	0	1	0	0	0
20	WCP	0	0	0	0	0	0	1	0	0	0	1	1
21	14A	0	6	0	4	1	0	10	0	2	0	0	0
22	14	0	6	0	4	1	0	10	0	2	0	0	0

Identification of LRUs:

23 - HDX RT 1E
18 - 3-Channel FSK Modem
16 - FSK Modem A
19 - Wide Band Modem
30 - Message Processor Unit, Black-2
20 - Force Synchronizer
12 - FDX SAT RT 1H (AC)
28 - Message Processor Unit, Red-3
21 - Command Post Synchronizer
44 - LOS R/T Control-3C
11 - Half Duplex SAT R/T (AC)
35 - Special I/O Logic/PS

Table C-2. DISTRIBUTION OF CONFIGURATIONS BY SITE AND OPERATE HOURS									
Airborne					Ground				
Site Configuration Number	Terminal Types in Configuration	Number of Sites	Number of Installs per Site	Monthly Operate Hours per Install	Site Configuration Number	Terminal Types in Configuration	Number of Sites	Number of Installs per Site	Monthly Operate Hours per Install
1	1	5	8	52.56	10	5D	2	1	730
		6	8	122.64	11	14B	2	1	730
		1	17	38.69	12	WCP	8	1	730
		3	[illegible]	122.64	13	14A	3	1	730
		1	11	91.25	14	14	1	1	730
		12	1	122.64					
		7	2	122.64					
2	1A	2	14	38.69	15	8A	3	1	730
3	2	0	-	0	16	C1	1	1	730
4	3	1	3	135.05	17	C3	1	1	730
		1	4	31.39	18	C9	1	1	730
		1	4	52.56					
		1	4	137.24	19	E12	1	1	730
		6	1	122.64	20	P8	1	1	730
5	1 and 2	2	1	128.48	21	P11	1	1	730
6	1 and 2	2	2	128.48	22	E3	1	1	730
7	1 and 3	1	1	94.38					
8	1 and 3	1	1	236.32					
9	1, 2, and 3	1	1	129.94					

LRU Grouping Number	LRU Types	Allocated Test Equipment Cost per LRU Type per Site	Total Number of Sites for LRU Types	Number of Equivalent Sites for LRU Types	Total Test Equipment Cost for Each LRU Type
1	11	18,197	48	22	400,334
	12	16,512	36	21	346,752
	23	15,147	54	25	378,675
2	16	25,226	45	40.5	1,021,653
	18	25,488	32	27.5	700,920
3	28	72,252	13	6.5	469,638
	30	72,252	26	19.5	1,408,914
4	44	17,137	54	54	925,398
5	20	17,579	43	40.5	711,950
	21	17,579	21	19.5	342,790
6	19	53,496	23	23	1,230,408
7	35	121,864	46	46	5,605,744

Table C-3. TEST EQUIPMENT COST ALLOCATION

Step 6. Divide the total cost in Step 5 by the number of LRUs for which the test equipment is used.

Step 7. Assign the cost derived in Step 6 to each of the LRUs on which the test equipment is used.

Step 8. For each LRU in the group, add all of the test equipment costs assigned to it. This cost is called "Allocated Test Equipment Cost per LRU Type per Site"; it appears in Table C-3.

Step 9. Identify the terminal types associated with each LRU.

Step 10. For each LRU, identify the specific sites at which that LRU will be located.

Step 11. Within each LRU grouping, assign an allocation weighting factor to each site. The factor is defined as the reciprocal of the number of LRU types (within each LRU grouping) that are located at that site. Thus, if an LRU grouping contains two LRU types used at site "A", the site is assigned an allocation weighting factor of 1/2 for that LRU grouping. If three LRU types from another LRU grouping are also located at site "A", the site is assigned an allocation factor of 1/3 for that LRU grouping.

Step 12. For each LRU type, obtain the sum of the allocation weighting for all the sites as derived in Step 11. This is called "Number of Equivalent Sites"; it is shown in Table C-3.

Step 13. Multiply the "Number of Equivalent Sites" by the "Allocated Test Equipment Cost per LRU per Site" to derive the "Total Test Equipment Cost for Each LRU Type".

To obtain an estimate of the depot test equipment costs, it was assumed that one complete test equipment set would be required at the depot for each of the LRU groups. The allocated costs per site for each of the LRUs given in Table C-3 were therefore used as the depot AGE costs for each of the LRUs.

5. LIFE-CYCLE-COST MODEL

The model used in this study was a modified version of one described in ARINC Research Publication 0637-02-1-1243, the final report on work performed for RADC under Air Force Contract F30602-C-0207.

The basic function of the model is to compare life-cycle costs under a totally organic maintenance concept with life-cycle costs under an RIW. The RIW period can be varied so that a number of alternatives may be examined. Because of the comparative nature of the model, total life-cycle costs are not calculated. Specifically, those costs which are believed not to vary with respect to the support concept are not considered. Examples are costs of installation and standard operation (e.g., power or fuel consumption).

Although the model is intended to be used in making warranty decisions, it can also be used to provide LCC information for organic maintenance only. Because of its general nature, the model may not include certain cost elements that are peculiar to a particular procurement. For this reason, a special cost category, "other", has been established to permit such unique costs to be inputted from the data base.

5.1 Premises and Assumptions

The major premises and assumptions under which the warranty life-cycle-cost model was developed are described in the following paragraphs.

5.1.1 Discounting

Discounting to reflect the time value of money is performed. An inputted discount rate of 0 is equivalent to an analysis based on undiscounted dollars.

5.1.2 Inflation

Inflation is not considered in the model, primarily because the model is used for comparative analyses rather than for prediction or

budgeting purposes. However, it is noted that if any data values are based on inflation factors, such as a contractor's warranty price bid in "then year" dollars, such values could be adjusted to normalize all cost values to the same basis.

5.1.3 Life-Cycle-Cost Calculation

Life-cycle costs can be calculated over the prescribed life cycle for four cases: (1) total organic maintenance over the life cycle, (2) an RIW for T_W years followed by organic maintenance for the remaining years, (3) warranty over the complete life cycle with no costs for transition to organic maintenance, and (4) warranty over the complete life cycle plus costs to acquire complete organic maintenance capability. The difference between cases (3) and (4) is that for the former we essentially assume that the equipment will be phased out after the prescribed life cycle, while for the latter the equipment will still be used and transition expenditures will have to be made such as for AGE, training, and data.

5.1.4 Equipment Maintenance Level

Under organic maintenance it is assumed that units (LRUs) are removed from the equipment (organizational-level maintenance) and are tested at the intermediate (base shop) level for failure verification. If a failure is verified, the unit is sent to a depot for repair or the subassembly (i.e., SRU) causing failure is identified and either discarded or sent to the depot for repair. Under warranty, base maintenance involves removal/replacement and failure-verification tests. The unit either is repaired at the base for special cases (e.g., fuse replacement, light-bulb replacement) or is sent to the contractor for repair. No actions at the subassembly or module level are performed by the military technicians when an RIW is in force.

5.1.5 Transition From RIW to Organic Maintenance

The procurement strategy for an RIW may be to defer buying support necessary for organic maintenance until transition to military maintenance occurs. Costs for such delayed purchases are included in the model, discounted as appropriate, when the warranty period is shorter than the equipment's useful life. It is assumed that AGE, training, and data purchased for the initial warranty have full value for application to organic maintenance requirements at transition. Therefore, if base AGE under organic maintenance costs \$X, and \$Y is the cost for base AGE under warranty, the cost for base AGE at transition is \$(X-Y). If this assumption is erroneous for a particular application, it can be corrected through an appropriate input in the "other" cost category.

5.1.6 Warranty Price

The model allows for either an inputted RIW price or for estimation of a price. The former would be used when contractor bid values are available, while the latter would be used in early feasibility studies or to perform an independent cost assessment.

5.1.7 Reliability Measure

It is assumed that mean time between failures is an adequate measure of equipment reliability and that the exponential distribution is an appropriate description of the failure pattern. However, the MTBF can vary over equipment life because of reliability growth.

5.1.8 Maintenance Demand

The model allows for including no-trouble-found events through a false-pull-rate factor defined to be equal to the conditional probability that a unit removed from an equipment is not failed. The false-pull rate is then equal to one minus the ratio of failure rate to removal rate.

5.2 Cost Categories

Thirteen major cost categories, listed below, have been established for calculating life-cycle costs. The first ten categories are believed to be consistent with those commonly used in Air Force life-cycle-cost studies. The remaining three have been added to cover aspects unique to an analysis of LCC under an RIW provision.

1. Acquisition Cost
2. Initial Spares
3. Replenishment Spares
4. On-Equipment Maintenance
5. Off-Equipment Maintenance
6. AGE
7. AGE Support
8. Training
9. Data
10. Inventory Management
11. RIW Price
12. MTBF Guarantee Value
13. Other Costs

5.3 Adaptation of Model to AFSATCOM

Two major changes were made to the original model for application to this study (these changes were necessitated by the different configurations and the heterogeneous deployment of these configurations throughout a large number of bases):

- A subroutine was developed for calculating the quantities of LRUs used at each of the sites based on the number of different configurations assigned to each site. The expected operate-hours total for each LRU at each of the sites was also calculated.
- A subroutine was developed for applying RIW reliability-growth factors to represent normal reliability maturation and the results of efforts to improve reliability through equipment-maintenance, test-equipment, or procedural improvements. Three factors are considered:
  - Warranty Incentive Factor. Being committed for repair of warranted units over a long period should provide incentive to the contractor to try to achieve the highest reliability consistent with program funds. Such a goal might be achieved through more intensive reliability design and testing efforts, as well as tighter production and quality-control procedures, than would normally be used under a procurement with no such commitment.
  - Warranty Maintenance Factor. A number of reliability studies have shown that a significant number of military maintenance events occur because of improper maintenance performed at the field levels. Inadequate repair of a malfunction or improper handling of the equipment may cause future failures that reflect more the capabilities of the technicians than the inherent equipment reliability. Under warranty, military maintenance is limited and the contractor is motivated to make a good repair to reduce the chances that the unit will be returned.
  - Reliability Growth. The reliability-growth factor is applied for both organic maintenance and RIW to represent normal reliability maturation and the results of efforts to improve reliability through equipment-maintenance, test-equipment, or procedural improvements. For electronic equipments, wearout is generally not a significant factor, and a majority of such equipments do exhibit increased MTBF as the equipment "matures". The growth factor under RIW is made a function of the RIW period; i.e., the longer the RIW period, the greater the expected growth in reliability.

6. DATA INPUTS FOR LCC MODEL

Table C-4 lists the required LRU procurement and maintenance data needed for inputs to the LCC model for calculating organic LCC and RIW/organic LCC. In addition, SRU data for each of the LRUs, such as cost, MTBF, and depot repair hours where applicable, are also used as data inputs to the LCC model. The basic data were obtained from Collins Radio Company's ORLA, Document Number RP-A01N-9-9, dated 25 October 1975, modified as appropriate to fit the requirements of the data inputs for the LCC model being used in this study.

7. DISCUSSION OF LCC OUTPUT

Table C-5 provides salient data generated by the LCC model, together with some intermediate calculations that may be of interest, for each of the LRUs -- i.e., the data for the RIW period that indicated the greatest savings resulting from use of an RIW in lieu of organic maintenance. Eight out of the twelve LRUs would require an RIW period of nine or ten years to maximize the LCC savings from using a warranty procurement approach rather than an organic one.

The number of failures expected to occur during the RIW period was obtained by multiplying the total operate hours per year by the average MTBF under RIW. The MTBF was taken to be one-half the predicted values given in the MITRE life-cycle-cost study. The average of vendor labor hours per repair action is based on a 90-percent learning curve and on the vendor labor hours for the 500th unit returned to the vendor. The labor hours for the 500th unit were estimated to be the average depot labor hours for repairing the SRAs. This information provides the basis for estimating the RIW cost to the government.

Table C-6 lists a number of percentages and ratios that provide some insight into the merits of using an RIW for any particular LRU. The estimated yearly RIW costs as a percent of the LRU costs appear to be lower than observed on other systems studied, such as the F-16. This is probably because of the low estimated average vendor labor hours or the low expected number of failures for the high-cost LRUs.

From the data presented thus far, some special comments about LRU 35 are appropriate. From Tables C-1 and C-2, it can be seen that 247 LRU 35s are required at 46 bases. At a cost of $121,864 per site (see Table C-3), the total base AGE would amount to $5.6 million. However, the cost of stocking base spares for a ten-year period in lieu of having AGE at the bases would amount to only $4.8 million. It would seem appropriate, therefore, to reconsider any base maintenance for LRU 35 for this first buy.

An examination of Table C-6 indicates that savings of 6.3 percent or greater could be realized for each of LRUs 28, 21, 19, 30, 20, and 44 if RIW were used. For none of the other LRUs would a saving of more than 3.6 percent be achieved.

Table C-4. **INPUT DATA FOR RIW EVALUATION**

Data Category	Symbol	LRU #23 HDX RT 1E 622-1564-001	LRU #18 3-CHANNEL FSK MODEM 622-1514-001	LRU #16 FSK MODEM-A 622-1513-001	LRU #19 WIDEBAND MODEM 622-1517-001	LRU #30 MESS. PROCESSOR UNIT-2 BLACK 622-1672-001	LRU #20 FORCE SYNCHRONIZER 622-1936-001
Shop labor hours	BLHO	2.0	3.5	2.2	3.9	6.0	2.5
Base AGE cost (dollars)	AGBO	378,675	700,906	1,021,673	1,230,408	1,408,914	711,950
Depot AGE cost (dollars)	AGDO	15,147	25,488	25,226	53,496	72,252	17,579
Man-weeks of initial training for shop maintenance	WTBO	3.6	1.8	1.2	3.6	2.4	1.8
Man-weeks of initial training for depot maintenance	WTDO	9	4.5	3	9	6	3
Number of "P-Coded" items	NPCO	18	16	16	19	18	16
Mean time between failures	MTBF	2,227	3,683	4,477	3,358	3,276	4,203
Unit cost	UC	13,200	13,348	7,680	22,016	35,915	4,730
Depot labor hours	DLHO	1.7	2.8	1.8	3.1	4.8	2.0
LRU parts repair costs	CMW	$200.00	$100.00	$100.00	$100.00	$150.00	$100.00
Proportion of LRUs that will be repairable in shop	RTS						0.80
Proportion of LRUs that will not be repairable in shop	NRTS						0.20
Turn-around time for RTS LRUs (days)	PBRTS						5
Turn-around time for NRTS LRUs (days)	PBNRTS						75
Turn-around time for modules repaired at shop (days)	PBM						15
Turn-around time for modules repaired at depot (days)	PDM						60
Protection level (approximately 93 percent)	ZP						1.52
Number of years of life	NY						10
Discount rate	DR						0.10
Minimum number of LRUs at base	MINLB						0
Minimum number of LRUs at depot	MINLD						5
Minimum number of modules at base	MINMB						0
Minimum number of modules at depot	MINMD						5
False-pull rate	FPR						0.2
Shop labor rate (dollars/hour)	BLRO						14.00
Organizational labor hours	OLH						1
Organizational labor rate (dollars/hour)	OLR						11.72
Depot labor rate (dollars/hour)	DLR						32.00
Rate of depot condemnation of modules	COND						0.02
Round-trip shipping costs for LRUs (dollars)	SCLO						40
Round-trip shipping costs for modules (dollars)	SCMO						10
Annual AGE support cost for base (proportion of initial procurement cost)	PAGB						0.07
Annual AGE support cost for depot (proportion of initial procurement cost)	PAGD						0.07
Training costs per man-week (dollars)	TCPW						500
Recurring training costs (proportion of initial training costs)	RTP						0.01
Total publications cost (dollars)	DTAO						100K
Inventory management cost/year/item (dollars)	CIM						165

ALUATION MODEL

U #20 ORCE RONIZER 936-001	LRU #12 FDX SAT RT 1H (AC) 622-2143-001	LRU #28 MESS. PROCESSOR UNIT-1 RED-3 622-1671-001	LRU #21 COMMAND POST SYNCHRONIZER 622-1937-001	LRU #44 LOS R/T CONTROL-3C 622-1536-001	LRU #11 HALF DUPLEX SAT R/T (AC) 622-1884-001	LRU #35 SPECIAL I/O LOGIC/PS 270-0312-020
2.5	1.3	6.5	2.7	1.4	2.1	1.7
1,950	346,752	469,638	342,790	925,398	399,740	5,605,744
7,579	16,512	72,252	17,579	17,137	18,197	121,864
1.8	3	2.4	1.8	0.6	3.6	1.2
3	1.5	1.5	1.5	1.5	1.5	1.0
16	18	18	16	7	18	12
,203	2,548	1,165	5,887	9,259	2,047	16,321
,730	13,101	35,546	6,602	3,120	15,234	11,770
2.0	1.6	5.2	2.2	1.1	1.7	1.4
100.00	$200.00	$100.00	$100.00	$80.00	$200.00	$100.00
0.80						
0.20						
5						
75						
15						
60						
1.52						
10						
0.10						
0						
5						
0						
5						
0.2						
14.00	THESE VALUES APPLY TO ALL LRUs.					
1						
11.72						
32.00						
0.02						
40						
10						
0.07						
0.07						
500						
0.01						
100K						
165						

Table C-5. PARTIAL OUTPUT FROM LIFE-CYCLE-COST MODEL

LRU Type	LRU Cost (Dollars)	Number of Installs	Total Operate Hours per Year (Thousands)	Average Organic MTBF (Hours)	Organic LCC (Millions of Dollars)	Organic LCC per Install (Dollars)	Most Economical RIW Period (Years)	Average RIW MTBF (Hours)	RIW LCC (Millions of Dollars)	RIW LCC per Install	Estimated RIW Cost (Thousands of Dollars)	Average Failures during RIW Period	Average Vendor Labor Hours
23	13200	320	397	1113	6.66	20812	7	1734	6.54	20437	621.8	1603	3.86
18	13348	266	539	701	7.12	26767	5	1005	7.11	26729	677.9	2682	3.56
16	7680	288	318	1615	4.40	17054	9	2697	4.25	16473	282.7	1061	3.74
12	13101	300	678	1274	6.93	23100	5	1827	6.75	22500	688.8	1856	3.5[illegible]
28	35546	32	42	583	2.84	88750	10	1003	2.57	80312	120.4	419	4.16
21	6602	52	127	1546	1.42	27308	10	2662	1.25	24038	107.4	477	2.63
19	22016	110	233	753	6.45	58636	8	1216	6.00	54545	541.4	1533	6.07
30	35915	48	80	558	5.75	119792	9	932	5.40	112500	253.3	773	3.80
20	4730	214	295	1727	2.84	13271	10	2974	2.64	12336	213.1	992	2.36
44	3120	620	763	4630	4.15	6694	10	7970	3.78	6097	165.5	957	1.91
11	15234	264	341	1023	6.47	24508	10	1762	6.37	24129	754.9	1935	3.68
35	11770	247	330	8160	11.71	47409	10	14050	11.45	46356	95.7	235	7.36

Table C-6. RIW FIGURES OF MERIT FOR 12 LRU TYPES

LRU Type	Yearly RIW Cost as a Percentage of LRU Cost	Yearly Savings under RIW as a Percentage of LRU Cost	LCC Savings under RIW as a Percentage of LCC under Organic Maintenance	Ratio of LCC to Purchase Price under Organic Maintenance	Ratio of LCC to Purchase Price under RIW Maintenance	LCC Unit Savings under RIW as a Percentage of LCC under Organic Maintenance	AGE Cost as a Percentage of Total Acquisition
23	2.1	0.28	1.8	1.58	1.55	1.9	9.3
18	3.8	0.03	0.1	2.01	2.00	0.5	20.5
16	1.6	0.76	3.4	2.22	2.14	3.6	52.8
12	3.5	0.46	2.6	1.76	1.72	2.3	9.2
28	1.1	2.37	9.5	2.50	2.26	9.6	47.6
21	3.1	4.95	12.0	4.14	3.64	12.1	105.0
19	2.8	1.86	7.0	2.66	2.48	6.8	53.0
30	1.6	2.03	6.1	3.34	3.13	6.3	85.9
20	2.1	1.98	7.0	2.81	2.61	7.1	72.1
44	0.9	1.91	8.9	2.15	1.95	9.3	48.7
11	1.9	0.25	1.5	1.61	1.58	1.9	10.4
35	0.3	0.89	2.2	4.03	3.94	2.2	197.0

8. SENSITIVITY ANALYSIS OF LCC MODEL

Table C-5 indicates that the maximum savings from the use of RIW are achieved in different periods for the various LRUs. However, because of the difficulties involved in administering warranty for different periods, it would be more practical to have all warranted LRUs under the same period of warranty coverage.

Table C-7 summarizes the anticipated RIW savings for LRUs 28, 21, 19, 30, 20, and 44 for RIW periods of one through ten years and various (0.25, 0.5, 1, 1.5) multiplying factors (k) for the MTBFs. For k = 1, the MTBF is one-half the predicted values given in the MITRE life-cycle-cost study. For the range of factors used, it appears that an RIW period of nine years would yield the maximum savings. Depending on the estimates of MTBF used, these savings varied between $1.4 million and $5.4 million for the ten-year life cycle. As a percentage of the organic life-cycle costs, the maximum savings varied from 6.5 to 15.4 percent.

Consideration should also be given to comments made in Section 7 of this appendix concerning the possible underestimating of the RIW costs.

Table C-8 provides estimates of the percentage savings under RIW for RIW costs that are 125 and 150 percent of the RIW costs originally estimated. This table indicates that the changes in expected savings range from 6.5 to 15.4 percent if the RIW costs were estimated correctly, while the range of expected savings is from 5.3 to 9.7 if the RIW cost was underestimated by 25 percent. These savings are also predicated on the assumption that the AGE would not be procured until after the RIW period was completed. If this assumption is not correct, e.g., the AGE is procured at the same time the units are acquired, a saving would not be realized for any of the situations in the table except for the situation in which the RIW is correctly estimated and the MTBF is actually 25 percent of the estimated field MTBF. Even in this case, the saving would be only 1.2 percent of the LCC under organic maintenance.

9. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are drawn and recommendations made on the basis of the foregoing analysis:

<u>Conclusions</u>

- The analysis of RIW suggests that it offers only a slight economic advantage over organic maintenance.
- Uncertainly in some of the input data estimates could reverse this slight economic advantage of RIW.
- Final judgment on the RIW decision must be based on the actual prices quoted by the contractor.

Recommendations

- The procurement of base AGE for LRU 5 should be reevaluated since it may be cheaper to fault-isolate only at the depot and procure additional spares for the base rather than procure AGE for each of the bases.
- It would be economically advantageous to procure LRUs 28, 21, 19, 30, 20, and 44 under RIW for some period between six and nine years, yielding a life-cycle-cost saving of at least 5 percent of the life-cycle cost under organic maintenance, provided the AGE is not procured until after the RIW period.

Table C-7. SAVINGS OF RIW LCC OVER ORGANIC LCC FOR VARIOUS MTBF RATIOS (θ_R)

LRU Type	Savings in Thousands of Dollars by RIW Period										Organic LCC (Thousands of Dollars)
	1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years	
$\theta_R = 1$											
28	-79	-9	55	92	157	179	221	232	237	269	2835
21	-60	-16	30	66	95	125	144	157	169	177	1424
19	-3	88	170	289	359	408	433	451	421	407	6449
30	-132	-23	92	159	231	291	298	334	350	333	5751
20	-41	11	54	88	135	160	180	194	199	201	2838
44	29	102	165	220	264	300	330	355	371	373	4154
Total LCC Difference	-286	153	566	914	1241	1463	1606	1723	1747	1760	23451
Percent Saving	-1.2	0.7	2.4	3.9	5.3	6.2	6.8	7.3	7.4	7.5	
$\theta_R = 0.5$											
28	-68	35	93	173	256	278	315	330	347	359	3369
21	-27	30	70	119	151	179	201	219	221	228	1672
19	158	320	508	622	691	745	761	804	760	680	8087
30	-115	68	210	316	406	497	519	530	532	467	6677
20	15	105	169	224	266	299	325	340	368	361	3324
44	140	267	372	460	531	588	636	674	699	698	4728
Total LCC Difference	103	825	1422	1914	2301	2586	2757	2897	2927	2793	27857
Percent Saving	0.4	3.0	5.1	6.9	8.3	9.3	9.9	10.4	10.5	10.0	
$\theta_R = 1.5$											
28	-102	-44	23	59	106	133	153	168	181	183	2634
21	-64	-30	5	36	58	78	96	113	122	130	1317
19	-53	53	144	236	283	322	358	371	376	362	5983
30	-292	-219	-183	126	170	192	218	249	245	234	4916
20	-39	5	40	74	102	125	146	157	179	184	2705
44	0	56	103	145	181	213	236	268	286	293	3964
Total LCC Difference	-550	-179	132	676	900	1063	1207	1326	1389	1386	21519
Percent Saving	-2.6	-0.8	0.6	3.1	4.2	4.9	5.6	6.2	6.5	6.4	
$\theta_R = 0.25$											
28	26	171	294	387	474	541	581	599	571	585	4367
21	1	86	158	222	268	306	334	346	354	348	2153
19	545	879	1130	1297	1420	1493	1521	1644	1617	1455	11280
30	2	252	415	753	862	970	1025	1055	1024	934	8527
20	118	253	364	453	524	576	611	636	690	678	4290
44	345	580	773	929	1057	1161	1245	1318	1366	1357	5875
Total LCC Difference	1307	2221	3134	4041	4605	5047	5317	5598	5622	5357	36492
Percent Saving	2.8	6.1	8.6	11.1	12.6	13.8	14.6	15.3	15.4	14.7	

Table C-8. ESTIMATED 9-YEAR RIW COSTS FOR 4 ESTIMATES OF MTBF (θ_R) AND 3 RIW COST FACTORS

(Thousands of Dollars)

LRU Type	$\theta_R = 1.5$			$\theta_R = 1.0$			$\theta_R = 0.5$			$\theta_R = 0.25$		
	RIW Cost Factor			RIW Cost Factor			RIW Cost Factor			RIW Cost Factor		
	1.0	1.25	1.5	1.0	1.25	1.5	1.0	1.25	1.5	1.0	1.25	1.5
28	76.6	95.8	114.9	111.3	139.1	167.0	210.4	263.0	315.6	398.1	497.6	597.2
21	68.0	85.0	102.0	99.2	124.0	148.8	189.7	237.1	284.6	363.3	454.1	545.0
19	408.3	510.4	612.5	588.3	735.4	882.5	1100.4	1375.5	1650.6	2062.8	2578.5	3094.2
30	173.4	216.9	260.3	253.3	316.6	380.0	484.4	605.5	726.6	928.7	1160.9	1393.1
20	134.9	168.6	202.4	196.9	246.1	295.4	377.4	471.8	566.1	724.4	1741.3	2089.6
44	104.8	131.0	157.2	153.0	191.3	229.5	292.3	365.4	438.5	562.3	702.9	843.5
Total RIW savings over organic maintenance cost	1389	1147	906	1747	1397	1045	2927	2263	1599	5622	3529	2099
RIW savings as a percentage of organic maintenance cost	6.5	5.3	4.2	7.4	6.0	4.5	10.5	8.1	5.7	15.4	9.7	5.8

APPENDIX D

SUMMARY OF OBSERVATIONS DURING TRIP TO PLATTSBURG AND VERONA

1. On May 16 and 17, Mr. R. Kentwortz (Sacramento ALC/MMER) and Mr. G. Harrison from ARINC Research, visited AFSATCOM installations at Plattsburg (FB-111) and Verona for the purpose of viewing the policies, procedures, completeness and integrity of reliability and maintainability problem-reporting during IOT&E. This report provides a summary of the observations and recommendations from the ARINC Research engineer.

2. Plattsburg (FB-111 installation)

Activities:

(a) Reviewed log book

(b) Observed aircraft installation

Observations:

(a) Equipment had required several maintenance actions but no failures had been charged. Test personnel were uncertain as to criteria for reporting actions and calling a failure.

(b) Sat Comm Control box installation is "blind". Adjacent LRU must be removed to disconnect and reconnect control box cables. At least two cases of bent connector pins have resulted from this installation configuration.

(c) Observed a broken connector (J-4) to 70 MHz receiver (AN/ARC-171). Probably caused by accident during maintenance of adjacent LRU.

3. Verona

Activities:

(a) Reviewed log books for terminals 12 and 9.

(b) Observed terminal 9 installation and test operation.

Observations:

(a) During the brief period in which terminal #12 was at Verona (5/1/75 - 5/9/75) it accumulated about 50 hours. During that time, it experienced a helix bearing failure in the high speed printer.

From the terminal 9 log, we observed at least five cases of mechanical failures (as opposed to electronic parts). The majority of these were in the printers.

4. General Conclusions

(a) Emphasis at both sites visited is on performance.

(b) Reliability and maintainability aspects of the IOT&E are not being accorded sufficient attention.

(c) IOT&E will not produce satisfactory R&M answers unless that area is emphasized.

5. Technical Conclusions

It is our assessment that the major source of R&M problems when the systems become operational will be:

- Electromechanical components
- Maintenance induced failures

6. Recommendations

(a) Provide increased attention to R&M aspects of IOT&E by ...

- assuring that test personnel have adequate resources and direction
- call for a test director's briefing to draw attention to the problem
- establish a roving R&M test coordinator to visit IOT&E sites and maintain interest and direction to R&M aspects of the test

(b) Provide a full-time, on-site representative at Collins to represent the Program Manager's interests in the reliability demonstration tests.

(c) Coordinate reliability demonstration problems with IOT&E problems and monitor Collin's activity in problem solving.

(d) Provide a clarification to the site test directors as to what types of terminal "anomalies" should be reported on the Form 258. (It is recommended that the same reporting criteria be used as are used for the 66-1 data collection system).

APPENDIX E

ASSESSMENT OF AFSATCOM SYSTEM DT&E/IOT&E FAILURE DATA

1. OBJECTIVE

The objective of this assessment is twofold: (1) to examine the abnormal incidents occurring during AFSATCOM DT&E/IOT&E operation in terms of their logistics impact; and (2) to assess the applicability of DT&E/IOT&E data for use as reliability data with the objective of reducing reliability testing.

2. METHOD

Three sources of data were employed in making the assessment: terminal operating logs and Air Force Forms 258 for the period January 1975 through August 1975, and the manufacturer's summary of field failures for the period late April 1975 through early June 1975. Three terminals were considered in the evaluation -- Terminals 1-1, 2-1, and 9-1. ARINC Research Corporation was supplied additional terminal operating log data for a supplemental one-month period for terminal 9-1. These data were compared with those of the preceding data period to determine the existence of system maturity/growth patterns.

The data were screened to obtain an itemized list of all "incidents" (or anomalies) occurring during the period. An "incident" is defined for this analysis as any abnormal or unexplained occurrence recorded in the operating logs while the terminal is powered up. These may range from a transient fault-light indication with no resulting fault to a failure resulting in system shutdown. Operating time for this analysis is the time recorded in the logs during which the system is "powered up." Bench (checkout) operating times for the various LRUs comprising the system are not included in the system operating time, because they are not included in the terminal logs. Under the exponential assumption of failure distribution, the exclusion of bench operating time and failures will probably not introduce bias into any estimates. A summary of incidents, paraphrased from the terminal logs, for each of the three terminal configurations is presented at the end of this Appendix (Tables E-3, E-4, and E-5), together with a summary (Table E-6) of incidents occurring during the supplemental data period for terminal 9-1.

Wherever possible, each incident in the tables was classified in terms of several pertinent characteristics:

- Were parts expended?
- Was maintenance performed?
- What LRU was affected?
- Was fault known or unknown (transient)?
- Was incident recurring (based on description in logs or form 258)?

The incidents thus classified were used as a basis for determining significant logistics parameters. These are listed in the data summary (Table E-1).

Table E-1. DATA SUMMARY OF TERMINAL LOGS AND FAILURE REPORTS

Statistic	Statistic Value		
	Terminal 1-1	Terminal 2-1	Terminal 9-1
Total Number of Incidents	83	34	53
Data-Collection Period (Months)	4.6	5.8	7.4
Total Operating Time (Hours)	687	400	1372
Mean Operating Time Between Incidents (Hours)	8	12	26
Number of Incidents Recurring Three or More Times	7	1	3
Total Repetitions	37 (45%)	12 (35%)	13 (25%)
Mean Operating Time Between Nonrecurring Incidents (Hours)	13	17	32
Incidents Requiring Maintenance Actions	29 (35%)	11 (32%)	38 (53%)
MTBNA (Operating Hours)	24	36	49
Transient (Unknown) Incidents	44 (53%)	22 (65%)	29 (55%)
Incidents Requiring Parts Expenditures	21 (25%)	6 (18%)	18 (34%)

3. LIMITATIONS

Certain limitations restricted the evaluation to a qualitative assessment of the data and their logistic impact. In many cases, the station logs did not contain sufficient information to permit determining the details of an incident or whether it was actually a relevant failure. The logs are prepared as a record of daily operations and are not intended to accommodate follow-up fault diagnosis. Therefore, identification of the failed LRU or module, the cause and conditions of failure, and parts and maintenance actions expended are not usually described in the logs. The Form 258s (available during the evaluation period) that follow up the faults identified in the logs did not, in a number of cases, provide this information because available resources and schedule did not appear to allow time for fault diagnosis and documentation. Failed LRUs were returned to the factory for repair and turnaround as soon as possible before a Form 258 was prepared in detail. In many cases where a transient fault indication was observed but the system continued to operate at or near acceptable levels, the terminal operation was continued without diagnosis of the fault indication.

The results of the data analysis are summarized in Table E-1, which lists the value of each data parameter for the three terminals. It should be noted that the terminal configurations are not identical, and therefore should not be compared with one another directly with regard to logistics parameters.

4. RESULTS

The data summary (Table E-1)* shows a value for mean time between incidents to indicate the overall frequency of observations for reference purposes. This value approximates a worst-case boundary for observed MTBF. It includes nonrelevant faults, unverified faults, transient incidents that may not have been faults at all, and recurring design faults. Therefore, it is not considered a realistic value for observed MTBF, but it may be representative of an initial logistics support impact.

The mean time between nonrecurring incidents shows the frequency of observed incidents, exclusive of those repeating incidents which occurred three or more times. The statistic is a better approximation of inherent MTBF than is mean time between incidents since it can be assumed that the contractor can correct "pattern" or repeating failures. The statistic is also an indicator of the dispersion or variety of incident types. The "mean time between maintenance actions" parameter listed in the table is based on only those incidents requiring maintenance actions and represents a measure of logistics support impact. This value approximates a more realistic estimate for observed MTBF than mean time between incidents.

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*Tables E-1 and E-2 do not include the results of the supplemental data period for terminal 9-1.

"Transient" incidents are listed in the table to show the percentage of incidents discussed in the terminal logs and Form 258s for which no cause or specific malfunctioning LRU is identified. This value is a significant percentage for each of the terminals listed. This parameter is driven largely by those incidents in which a transient anomaly or fault indication was observed, after which the terminal continued to operate normally. It is also affected by the adequacy of the data available during the evaluation period to diagnose faults, as discussed previously.

The percentage of total incidents that were maintenance actions requiring the expenditure of parts is listed in the table to provide a measure of logistics support impact. More than half of those incidents which required maintenance actions also required parts expenditure.

Table E-2* presents a summary of incidents, paraphrased from the logs and Form 258s, that appeared to be recurring anomalies. The table gives a brief descriptive title and number of repetitions for each recurring incident. Inspection of the table shows that the three terminals did not share the same recurring incidents even though terminals 1-1 and 2-1 contain many identical LRUs and all three terminals perform similar functions. It should be noted that the recurring incidents are selected and classified on the basis of description or fault indication, not equipment indenture. Thus the LRU-level incident "transmitter fault light", reported in the logs, is classified as a recurring incident in the table, as is the module-level incident "printer carriage lock-up", whereas the module-level faults "printer carriage lock-up" and "printer feed malfunction" are considered different incidents, even though they are in the same LRU, because their descriptions or fault indications are different.

5. CONCLUSIONS

Evaluation of the data yielded specific conclusions concerning the AFSATCOM system and general conclusions regarding the applicability of DT&E/IOT&E data for reliability assessment.

5.1 Specific Conclusions

The data do not reveal any trends in common failure symptoms from one terminal to another, as evidenced by Table E-2; this table shows seven different types of recurring incidents for terminal 1-1, one type for terminal 2-1, and three types for terminal 9-1; however, none of these recurring incident descriptions was common to more than one terminal.

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*Tables E-1 and E-2 do not include the results of the supplemental data period for terminal 9-1.

Table E-2. SUMMARY OF RECURRING INCIDENTS	
Incident	Number of Occurrences
Terminal 1-1	
Printer Carriage Lock-Up	5
Printer Feed Malfunction	3
Satellite R/T Control Fault Light	11
EAM Alarm Reset Fault	3
Auto Transmit Keyboard Control Fault	8
Intermittent Preamplifier Fault (unknown)	3
Noisy Transmission During Take-Off	4
Total Incidents (Recurring & Nonrecurring)	(83)
Terminal 2-1	
Transmitter Fault Light	12
Total Incidents (Recurring & Nonrecurring)	(34)
Terminal 9-1	
False Acquisition	6
False Synchronization Mode Change	4
DCSU Malfunction	3
Total Incidents (Recurring & Nonrecurring)	(53)

Additional specific conclusions are as follows:

- Individual terminals exhibited a wide range or dispersion of incident types without emphasis on a particular fault indication or LRU, with the exception of the ASRs (printers) and the transmitter fault light (terminal 2-1). Late in the data period the printers underwent a corrective modification that appeared to correct these problems. The transmitter fault-light indications were transient or intermittent incidents that did not appear to cause a malfunction.
- Comparison of the supplemental data (Table E-6) for terminal 9-1 with the data from the primary evaluation period indicates that during the final month of data collection, there was an increase in mean time between maintenance actions and mean time between parts actions. The statistical ("F") test indicated that there would be only a 10 percent chance that these higher mean values could have been observed without a real increase in mean values over the previous period.
- A significant number (approximately half or more) of the incidents described in the data were "transient" or intermittent anomalies for which no cause was determined (see Table E-1). These generally did not result in terminal shut-down or expenditure of parts and maintenance according to the data. This percentage might be considered a measure of the uncertainty involved in assessing the system's failure modes and mechanisms, and of the inadequacy of the data for detailed failure analysis.
- The DT&E/IOT&E data were useful in determining logistics impact parameters (see Table E-1). However, in some cases detailed failure information, such as repair actions, parts expended, or cause and condition of failure, could not be determined. Therefore, MTBF could not be calculated for the data period.

5.2 General Conclusions

The AFSATCOM DT&E/IOT&E data characteristics discussed in this appendix are probably typical of such data. These lead to the general conclusion that it is difficult to substitute such data for reliability-test demonstration data. Dedicated spares, maintenance, and schedule resources are often not available to support detailed failure analysis and documentation of field faults. The different purposes that are intended to be served by reliability testing and by IOT&E and DT&E testing are probably most responsible for the inherent difficulties in using the latter test results to satisfy the former test requirements. Reliability-demonstration acceptance tests such as those described in MIL-STD-781 are intended as statistically based accept-reject tests. That we can use the data from such a test to make a point estimate of MTBF is not important to the decision to accept or reject the equipment. The tests are designed to accept (or reject) the equipment on the basis of a number of observed failures. The definition of "failure" is

very important, and the classification of "incidents" that occur during the test as failures or nonfailures is often difficult and subject to interpretation even though such decisions are made by those trained to do so. It is not surprising, then, to encounter even greater difficulty in defining failures during IOT&E and DT&E. The personnel involved in such tests are apt to be operationally oriented, and this leads to an emphasis on equipment performance.

For these reasons, it is concluded that DT&E/IOT&E data are not generally useful for reliability demonstration and that such use should not be attempted. DT&E/IOT&E data are, however, useful for providing important logistics insight, as discussed previously under specific AFSATCOM conclusions. They may also be used to identify the most serious reliability problems.

Table E-3. INCIDENT SUMMARY: TERMINAL 1-1, MINOT			
No.	Date	Total Time (Hours)	Remarks
1	3/1	12.5 S 7.5 L	Depot repair; Form 258 S/N 715601; printer, carriage lock-up; condition lasted 0.5 - 1.0 hour (transient).
2	3/6	44.42S 7.5 L	Printer, carriage lock-up (see 1); condition lasted 0.5 hour (transient).
3	3/6	44.42S 7.5 L	Transient Satellite R/T control fault; Form 258 S/N 715620; condition lasted 0.5 hour; continued operations and fault disappeared.
4	3/7	61.25S 7.5 L	Depot repair; Form 258 S/N 715621; synchronizer random advance in TDM 2 mode; continued operations (transient).
5	3/10	94.75S 7.5 L	Transient; continued operations (same as 2 and 3).
6	3/10	94.75S 7.5 L	Transient; continued operations (same as 2 and 3).
7	3/11	108.75S 7.5 L	Carriage lock-up (see 1); Satellite R/T control fault light (see 3); continued operations (transient).
8	3/11	108.75S 7.5 L	Carriage lock-up (see 1); Satellite R/T control fault light (see 3); continued operations (transient).
9	3/12	125.75S 7.5 L	Satellite R/T control fault light (see 3); condition lasted 1 hour (transient).
10	3/15	175.75S 7.5 L	Satellite R/T control fault light (see 3); condition lasted 15 - 20 minutes (transient).
11	3/17	193.3S 7.5 L	Satellite R/T control fault light (see 3); condition lasted 15 - 20 minutes (transient).
12	3/18	209.55S 7.5 L	Satellite R/T control fault (see 3); condition lasted 15 - 20 minutes (transient).
13	3/19	226.05S 7.5 L	Satellite R/T fault (see 3); condition lasted 15 - 20 minutes (transient).
14	3/19	226.05S 7.5 L	EAM alarm malfunction; continued operations (transient).
15	3/20	242.55S 7.5 L	EAM alarm malfunction; continued operations (transient).

S = Satellite
L = Line of sight

(continued)

Table E-3. (continued)			
No.	Date	Total Time (Hours)	Remarks
16	3/21	258.72S 7.5 L	Carriage-return fault; 1-hour alignment made by Collins representative.
17	3/22	275.22S 7.5 L	Printer would not print first 4 characters; continued operations (transient).
18	3/22	275.22S 7.5 L	RCV busy light/printer fault. Printed bad message. Repeatable fault.
19	4/1	345.55S 7.5 L	Depot repair; Form 258 S/N 715603; printer/keyboard malfunction. Remove and replace printer (ASR).
20	4/12	373.02S 13.0 L	Form 258 S/N 715624; R/T control fault light/modem lit. Continued operations. Condition lasted 0.5 hour (transient).
21	4/14	375.89S 17.75L	Same as 20 (transient).
22	4/21	381.12S 24.00L 3.75M	Satellite R/T control fault light lit with modem control in "control test". Condition lasted 15 minutes; continued operations (transient).
23	4/22	383.62S 24.00L 3.75M	Form 258 S/N 715625 and 715609; modem fault light lit while automatic transmit keyed. Condition lasted 15 minutes; continued operations.
24	5/10	398.25S 46.15L 9.00M	Form 258 S/N 715609, 715608, 715607, and 715725. Fault light on FSK modem control in operate position. Could not isolate (see 23) (automatic transmit).
25	3/15	175.75S 7.5 L	Depot repair; Form 258 S/N 715602; printer would not print certain characters (S and O).
26	5/15	407.9 S 49.55L 11.00M	Depot repair; Form 258 S/N 715605; EAM alarm reset fault.
27	5/15	407.9 S 49.55L 11.00M	Remove and replace R/T; Form 258 S/N 715608, 715609, 715607; HDX FSK control fault light in operate, preamplifier, receiver, and transmitter positions. Transmitter-receiver failure (see 23 and 24).
28	5/16	410.85S 55.55L 11.00M	Form 258 S/N 715607, 715608, 715609; HDX FSK control fault light (see 27).

M = Line of sight/modem loop

(continued)

Table E-3. (continued)			
No.	Date	Total Time (Hours)	Remarks
29	5/16	410.85S 55.55L 11.00M	EAM alarm reset failure.
30	5/16	410.85S 55.55L 11.00M	Intermittent fault in message controller (push-button test switch).
31	5/17	411.85S 55.55L 11.00M	Depot repair (force synchronizer); EAM alarm failed to function.
32	5/17	411.85S 55.55L 11.00M	Form 258 S/N 715627; test connector to J5 on modem found loose (pin 12).
33	5/29	417.85S	Form 258 S/N 715628; test instrument "T" box fault.
34	5/30	423.95S	Remove and replace synthesizer module; Form 258 S/N 715607, 715608; fault indication (BITE) in SATL and LOS modes in operate, receiver, preamplifier, and transmitter positions.
35	5/30	423.95S	Remove and replace oven standard; Form 258 S/N 715609, 715607; R/T frequency standard was 92 Hz high; fault light in modem position.
36	5/31	425.45S	Form 258 S/N 715606; R/T connector J5; intermittent fault (open pin 21).
37	6/2	429.08S 81.55L 12.60M	Remove and replace R/T and power supply; R/T fault.
38	6/3	434.08S 81.55L 12.60M	Remove and replace R/T; R/T fault.
39	6/3	434.08S 81.55L 12.60M	Preamplifier fault.
40	6/3	434.08S 81.55L 12.60M	Synthesizer fault.
41	6/3	434.08S 81.55L 12.60M	1-MHz standard.

(continued)

Table E-3. (continued)			
No.	Date	Total Time (Hours)	Remarks
42	6/3	434.08S 81.55L 12.60M	HDX.
43	6/3	434.08S 81.55L 12.60M	See 35: oven standard fault.
44	6/7	445.12S 93.30L 13.60M	Transient fault; Form 258 S/N 715613; time slot TX malfunction and printer malfunction.
45	6/9	446.12S 93.3 L 13.6 M	Depot repair; transient fault; Form 258 S/N 715613; printer malfunction (ASR).
46	6/10	449.12S 98.3 L 16.7 M	Depot repair; Form 258 S/N 715610; printer feed malfunction.
47	6/10	449.12S 98.3 L 16.7 M	Form 258 S/N 715611; force synchronizer fault; time slot/automatic transmit in TDM 1 mode (transient).
48	6/10	449.12S 98.3 L 16.7 M	Form 258 S/N 715612; force synchronizer fault; random display error (transient).
49	6/11	451.72S 107.5 L 20.7 M	Form 258 S/N 715614; transient noise lock; force synchronizer fault, intermitten; three times.
50	6/11	451.72S 107.5 L 20.7 M	Form 258 S/N 715612; force synchronizer; transmit mode fault, random display (see 48) (transient).
51	6/12	453.97S 107.05L 20.7 M	Remove and replace connectors J4, J7; cabling fault (modem connectors).
52	6/13	457.22S 107.5 L 20.7 M	Transient fault; Form 258 S/N 715615; synchronizer mode malfunction; force synchronizer.
53	6/16	466.22S 107.05L 20.7 M	Transient; Form 258 S/N 715604; intermittend pre-amplifier fault. Could not duplicate.

(continued)

Table E-3. (continued)			
No.	Date	Total Time (Hours)	Remarks
54	6/17	469.82S 112.05L 24.7 M	Transient (unknown); Form 258 S/N 715617; LOS transmission broken 15 minutes.
55	6/17	469.82S 112.05L 24.7 M	Transient preamplifier fault - intermittent (see 53 and 57); Form 258 S/N 715604.
56	6/17	469.82S 112.05L 24.7 M	Form 258 S/N 715610; printer feed malfunction (see 46).
57	6/18	473.12S 112.05L 24.7 M	Transient preamplifier fault, intermittent; Form 258 S/N 715604 (see 53).
58	6/18	473.12S 112.05L 24.7 M	Auto transmit keyboard control fault (transient).
59	6/18	473.12 112.05L 24.7 M	Transient noise lock; Form 258 S/N 715616.
60	6/18	473.12S 112.05L 24.7 M	Force synchronizer fault during EAM; Form 258 S/N 715618 (transient).
61	6/18	473.12S 112.05L 24.7 M	Force synchronizer fault; TDM1 indicator, Form 258 S/N 715619.
62	6/19	477.02S 119.75L 29.6 M	Transient auto transmit keyboard malfunction (see 58).
63	6/20	477.02S 119.75L 29.6 M	Printer feed malfunction; remove and replace printer; Form 258 S/N 715629.
64	6/27	477.02S 126.75L 29.6 M	Remove and replace R/T and LOS control and synthesizer; Form 258 S/N 715630.
67	6/29	479.82S 126 L 29.6 M	Remove and replace EAM MCN 110; repeating EAM-alarm-reset fault.

(continued)

Table E-3. (continued)			
No.	Date	Total Time (Hours)	Remarks
68	6/29	479.82S 126 L 29.6 M	Nonrecurring overflow lamp fault; Form 258 S/N 715631 (transient).
69	6/29	479.82S 126 L 29.6 M	Form 258 S/N 715632; keyboard lock-up (operator error).
70	6/29	479.82S 126 29.6 M	Nonrecurring EAM malfunction; Form 258 S/N 715634 (transient).
71	6/29	479.82S 126 L 29.6 M	Synchronizer fault; Form 258 S/N 715635.
72	6/30	481.07S 126.00L 29.00M	Synchronizer lock fault; Form 258 S/N 715637.
73	7/2	483.67S 129.4 L 29.6 M	Intermittent broken transmission, recurring problem; Form 258 S/N 715617 (transient).
74	7/2	483.67S 129.4 L 29.6 M	Transient printer fault; Form 258 S/N 715638.
75	7/3	484.42S 129.4 L 29.6 M	Remove and replace transfer relay; intermittent fault; Form 258 S/N 715639.
76	7/8	487.67S 129.4 L 29.6 M	Remove and replace preamplifier; transient preamplifier fault - low AGC; Form 258 S/N 028288.
77	7/11	492.47S 136.30L 29.6 M	Remove and replace printer; transient printer fault - loss of print; Form 258 S/N 026289.
78	7/15	497.77S 145.6 L 29.6 M	Transient force synchronizer fault - random display (see 48); continue operations; Form 258 S/N 715612.
79	7/15	497.77S 145.6 L 29.5 M	Transient auto transmit fault, TDM1 (see 47); Form 258 S/N 715611.

(continued)

Table E-3. (continued)			
No.	Date	Total Time (Hours)	Remarks
80	7/15	497.77S 145.6 L 29.6 M	Transient noisy/broken transmission during take-off (see 73); Form 258 S/N 715617.
81	7/17	502.07S 155.6 L 29.6 M	EAM alarm fault; Form 258 S/N 733009.
82	7/17	502.07S 155.6 L 29.6 M	Satellite R/T control display fault; 1st and 4th digits not lit; Form 258 S/N 733010.
83	7/17	502.07S 155.6 L 29.6 M	Satellite R/T control panel edge lights out; Form 258 S/N 733012.
84	7/17	502.07S 155.6 L 29.6 M	Transient noisy/broken transmission; Form 258 S/N 715617.

Total hours = 687.27

MTBF = 8.18 hours

Total incidents = 84 -- one operator error fault (not applicable)

Total transient problems (fault unknown) = 44 (some repeating) for which no diagnosis is indicated in data

Maintenance actions = 29

Parts actions = 21

Recurring incidents (3 or more repetitions) = 7

Total recurring = 37

Table E-4. INCIDENT SUMMARY: TERMINAL 2-1, C-141			
No.	Date	Total Time, Hours/ Minutes	Remarks
1	2/12	30/3	Transient - low AGC voltage.
2	2/19 2/20 3/11	90/0 90/0 90/0	Improper AGC. Remove and replace preamplifier, R/T, etc., parts.
3	4/1	97/35	Transient; transmitter fault; continue operations.
4	4/2	99/65	Transient; transmitter fault; continue operations.
5	4/3	104/25	Remove and replace connector parts (transmitter fault).
6	4/3	104/25	Repair breakout box; no SQM - repair.
7	4/3	104/25	Transient; ASR fault; printer linefeed malfunction.
8	4/9	113/47	Checkout transmitter fault light; transient; continue operations.
9	4/14	120/21	Transient; transmitter fault light; continue operations.
10	4/16	132/29	Transient; transmitter fault light; continue operations.
11	4/22	--	Transient; transmitter fault light; continue operations.
12			Checkout AGC malfunction, R/T.
13	5/5	202/57	BITE check FSK transmitter fault; transient; continue operations.
14	5/11	225/29	Maintenance action; transmitter fault.
15	5/13	234/49	Transient; transmitter fault; continue operations.
16	5/16	244/43	Transient; transmitter fault; continue operations.
17			Transient; receiver malfunction.
18	6/19	281/17	Remove and replace preamplifier; receiver malfunction (preamplifier).
19	6/25	292/53	Transient receiver malfunction.
20	6/27	302/26	Maintenance action; printer hang-up.
21	7/3	317/14	Transient transmitter fault light; continue operations.
22			Maintenance action; data-punch malfunction.

(continued)

Table E-4. (continued)			
No.	Date	Total Time, Hours/ Minutes	Remarks
23	7/7	332/54	Transient transmitter fault; continue operations.
24	7/9	344/21	Transient transmitter fault (not same as above); continue operations.
25	7/11	350/35	Transient transmitter fault light; continue operations.
26	7/12	352/46	Maintenance action; ASR/modem fault - transmitter.
27	7/15	355/57	Transient receiver malfunction.
28	7/16	358/41	Remove and replace keyboard (keyboard failure).
29	7/19	375/19	Transient transmitter fault.
30	7/21	382/18	Unknown repeating transient transmitter fault; continue operations.
31	7/23	389/58	Transient transmitter fault; continue operations.
32	7/23	389/58	Remove and replace transmitter - ASR failure.
33	7/25	399/01	Transient transmitter fault at turn-on.
34	8/4	399/01	Remove and replace ASR (faulty).
END	8/6	399/29	

Total Hours = 399.5

Total Incidents = 34

MTB Incidents = $\frac{399.5}{34}$ = 11.8 Hours

Maintenance Actions = 11

MTBMA = 36 Hours

Transient faults = 22 = 65%

Incidents reported requiring parts = 6

Recurring problem - transmitter fault light (approximately 12) = 35%

Table E-5. INCIDENT SUMMARY: TERMINAL 9-1, VERONA			
No.	Date	Total Time, Hours/ Minutes	Remarks
1	7/15	1273/13	Transient; Form 258 S/N 735591; false acquisition (noise lock).
2	7/17	1289/06	Transient MPU fault.
3	7/19	1303/49	Transient false lock-up, receiver.
4	7/21	1318/31	Transient; Form 258 S/N 735591; noise lock (see 1).
5	7/24	1347/68	Transient MPU fault.
6	7/25	1356/28	Form 258 S/N 735591; false acquisition (transient).
7	7/31	1371/33	Transient; Form 258 S/N 735591; false acquisition.
8	6/18	1100/51	Remove and replace LRU; transient; Form 258 S/N 735591; false acquisition.
9	6/20	1112/15	Transient; Form 258 S/N 735590; modem malfunction - false mode change to TDM 2.
10	6/24	1130/31	Transient; parts maintenance; install printer modification kits.
11	6/28	1154/06	Remove and replace receiver/transmitter; Form 258 S/N 735616; faulty.
12	7/1	1173/53	Transient signal loss.
13	7/8	1211/06	Remove and replace preamplifier; Form 258 S/N 735628; modem fault (preamplifier).
14	6/5	1023/02	Form 258 S/N 735571; maintenance and parts; ASR failure.
15	6/8	1035/36	Form 258 S/N 735587; maintenance and parts; install (replace) DSCU 3.
16	6/9	1044/46	Form 258 S/N 735586; maintenance and parts; install modem and ASR (see 14).
17	6/10	1049/42	Transient ASR rese malfunction.
18	6/12	1062/30	Form 258 S/N 735588; data errors - garbled message (transient).
19	6/12	1062/30	Form 258 S/N 735591; false acquisition (transient).
20	6/13	1069/44	Maintenance action; From 258 S/N 735594; printer carriage-return fault.
21	6/13	1069/44	Form 258 S/N 735590; false synchronization mode change (see 9) (transient).

(continued)

Table E-5. (continued)			
No.	Date	Total Time, Hours/ Minutes	Remarks
22	6/16	1082/31	Form 258 S/N 735590; false synchronization mode change (transient).
23	6/17	1091/08	Form 258 S/N 735590; false synchronization mode change (transient).
24	5/11	874/27	Noise lock (transient).
25	5/15	897/50	Maintenance and parts; unknown transient modem fault (DCSU); Form 258 S/N 735554.
26	5/16	910/26	Remove and replace DCSU; Form 258 S/N 735555; no fault; suspected DCSU fault; ZNR header error.
27	5/17	926/56	Maintenance action; Form 258 S/N 735555; DCSU fault.
28	5/18	933/00	Form 258 S/N 735555; DCSU fault - KG-36 failure.
29	5/20	941/28	Transient problem - message lost (one time).
30	5/22	947/56	Transient noise problem.
31	5/27	960/26	Transient - intermittent modem fault.
32	6/3	1005/24	Form 258 S/N 735585; transient; 1 × 3 modem fault light.
33	4/22	776/25	Remove and replace modulator; Form 258 S/N 735510; 70-Hz leak in 1 × 3 modem.
34	4/23	780/05	Remove and replace modulator; Form 258 S/N 735513; ZNR header error, FSK modem fault.
35	4/24	791/38	Maintenance action; Form 258 S/N 755513; control head fault.
36	4/29	823/34	Unknown transient, garbled messages, 1 hour.
37	4/30	836/06	Transient transmission faults, 1 hour.
38	5/10	870/17	Depot repair, Form 258 S/N 739552, printer fault.
39	3/25	594/57	Maintenance action; printer repairs.
40	3/27	607/52	Depot repair/parts; Form 258 S/N 889622; 1 × 3 modem breaker; Satellite R/T control fault.
41	4/3	639/53	Maintenance action/parts; Form 258 S/N 889630; modem cable fault.
42	4/3	639/53	Maintenance action/parts; Form 258 S/N 889632; R/T unit fault.

(continued)

Table E-5. (continued)			
No.	Date	Total Time, Hours/ Minutes	Remarks
43	4/7	666/31	Maintenance action - checkout; Form 258 S/N 889636; transient transmitter fault.
44	2/21	338	Transient transmitter fault.
45	2/24	340	Maintenance action; 1 × 3 modem - loose cable.
46	2/26		Maintenance/parts; ASR pulley fault (printer).
47	2/27		Transient 1 × 3 FSK modem fault (connector).
48	3/3		Transient attenuation problem.
49	3/17		Maintenance action; printer hunting.
50	3/21		Transient ASR fault.
51	1/21		Depot repair; Form 258 S/N 889628; ASR fault (broken wire).
52	1/21		Depot repair; Form 258 S/N 889627; ASR fault.
53	1/26		Maintenance/parts; Form 258 S/N 889631; antenna fault (cable).

Total Hours = 1372

Transients = 29

Maintenance Actions = 28

Parts Actions = 18

Recurring Incidents = 13

Table E-6. TERMINAL 9-1 SUPPLEMENTAL DATA, STATION LOG SUMMARY

No.	Date	Total Time, Hours/ Minutes	Maintenance	Parts	Remarks
1	7/31	1371/33	No	No	Transient, false acquisition; Form 258 SN 735591.
2	8/6	--	No	No	Transient, false synchronization mode change.
3	8/6	--	Yes	Yes	R/T failure, Form 258 S/N 735648.
4	8/6	--	Yes	No	R/T fault, Form 258 S/N 735649.
5	8/7	1424/7	No	No	Transient, false acquisition Form 258 S/N 735591
6	8/7	1424/7	No	No	Transient, false synchronization mode change; Form 258 S/N 735590.
7	8/8	1436/20	No	No	Transient, false acquisition; Form 258 S/N 735591.
8	8/12	1457/20	No	No	Transient, false acquisition; Form 258 S/N 735591.
9	8/21	1528/4	Yes	No	Modem fault, transient.
10	9/10	1626/52	No	No	Transient transmission fault.
11	9/11	1631/42	No	No	Transient tramsmission fault.
12	9/15	1646/4	No	No	Transient synchronization problems.
13	9/15	1646/4	No	No	Transient R/T fault.
14	9/22	1691/4	Yes	Yes	Modem fault.
15	9/23	--	Yes	No	Synchronization malfunction.
16	9/26	1721/57	No	No	Transient modem fault.

Total Hours = 350.4 | MTBMA = 70 Hours

Total Incidents = 16 | MTB Incidents = 22 Hours

Maintenance Actions = 5 | Transients = 11 = 69%

Parts Actions = 2